Correlation Between Standard Upper Extremity Impairment Measures and Activity-based Function Testing in Upper Extremity Cerebral Palsy

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Background: Although the treatment of cerebral palsy should be based on improving function as assessed by measures of impairment, activity, and participation, the standard indications for surgical treatment of upper extremity cerebral palsy (UECP) are impairment measures, primarily active and passive range of motion (ROM). Recently, validated activity measures have been developed for children with UECP. The purposes of this study were to determine the relationship between impairment and activity measures in this population, and whether measures of activity correlate with each other.

Methods: A total of 37 children, ages 5 to 16 years, who met standard ROM surgical indications for UECP were evaluated with the impairment measures of active and passive ROM and stereognosis, as well as 3 activity measures [Assisting Hand Assessment (AHA), Box and Blocks test, and the Shriners Hospitals Upper Extremity Evaluation Dynamic Positional Analyses (SHUEE DPA)]. Impairment measures were correlated with activity measures using Spearman rank correlation coefficients.

Results: Impairment measures showed inconsistent correlation with activity measures. Of the 12 comparisons, only 4 correlated: active forearm supination ($\rho = 0.47$, $P = 0.003$), wrist extension ($\rho = 0.55$, $P = 0.001$), and stereognosis scores ($\rho = 0.54$, $P = 0.001$) were correlated with AHA; and wrist extension was correlated with the SHUEE DPA ($\rho = 0.41$, $P = 0.01$). When the results of activity tests were compared, the AHA was correlated with the Box and Blocks tests ($\rho = 0.63$, $P < 0.001$), and the SHUEE DPA and Box and Blocks tests were correlated with each other ($\rho = 0.35$, $P = 0.04$).

Conclusions: The goal of surgery in UECP is to improve the child's ability to perform activities, and ultimately to participate in life situations. Impairment measures, such as ROM, were inconsistently correlated with validated measures of activity. Some activity measures correlated with each other, although they did not correlate with the same impairment measures. We conclude that impairment measures, including ROM, do not consistently predict functional dynamic ROM used to perform activities for children with UECP. Activity limitation measures may provide more appropriate indicators than impairment measures for upper extremity surgery for this population.

Level of Evidence: Level II—diagnostic.

Key Words: upper extremity cerebral palsy, function, surgical indications, World Health Organization International Classification of Functioning, activity, impairment

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Cerebral palsy (CP) includes a spectrum of neuromuscular conditions defined as "a group of permanent disorders of the development of movement and posture, causing activity limitation, that are attributed to nonprogressive disturbances that occurred in the developing fetal or infant brain."[1] The manner in which the muscular dysfunction manifests (tone) may be described as spastic, dyskinetic, ataxic, hypotonic, or mixed. Spastic CP is the most common manifestation and is the most amenable to surgical treatment, although most children have a combination of tone types.[2] In spastic upper extremity cerebral palsy (UECP), the most common deformities are elbow flexion, forearm pronation, wrist flexion, ulnar deviation, and thumb in palm.[3]

The World Health Organization International Classification of Functioning, Disability and Health (WHO ICF) defines a health condition as dysfunction at the levels of impairment, activity limitations, and participation restrictions. Impairment is a problem with body function or structure. Activity limitation is difficulty with the execution of a task. Participation restrictions are limitations on life involvement.[4] As defined by the WHO ICF, measurement of disability in children with CP includes measurement of impairment, activity limitations, and participation restriction.

A child with UECP has restricted motion in the forearm, wrist, and thumb, which may vary with effort and task. The classic indications for surgical treatment of UECP are all measures of impairment, focused primarily on loss of active and passive range of motion (ROM), as detailed below.

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To improve supination for children with ≤0 degrees active supination, Strecker et al[5] recommended tenotomy or rerouting of the pronator teres (PT). For correction of wrist flexion deformity with flexor carpi ulnaris (FCU) as the primary deforming force, Green, Banks, and others recommended FCU to extensor carpi radialis brevis (ECRB) transfer to improve active wrist extension and supination.[6,7] For correction of the thumb clenched inside the fingers when the child makes a fist, Manske[8] recommended adductor pollicis (AP) release and rerouting of extensor pollicis longus (EPL) from the third to first extensor compartment. Although surgeons experienced in the care of children with UECP may take into account other factors such as ability to perform activities, sensibility, and cognitive impairment, these recommendations, which consist of deficiencies in active or passive ROM in the forearm, wrist, and thumb, respectively, comprise the standard indications for these operations.

Underlying the use of active ROM as a surgical indication is the presumption that these measures are correlated with limitations in activity and participation. However, for children with CP, it has been shown that there is, at best, a fair correlation between lower extremity ROM (as measured by physical examination) and lower extremity kinematics (as measured by quantitative gait analysis).[9] The relationship between impairment and activity measures is not well described for the upper extremity in CP. Several measures of pediatric activity limitations have recently been validated and/or normed, including the Assisting Hand Assessment (AHA),[10] Box and Blocks test,[11,12] and the Shriners Hospitals Upper Extremity Evaluation (SHUEE).[13] The purpose of this study was to determine the correlations between impairment (restricted ROM) and activity measures, and among the various activity measures. The hypotheses of this study were that impairment and activity measures are not correlated, but that activity measures are correlated with each other.

METHODS

This study was performed with informed consent by the parents and the assent of all subjects, and was approved by the Institutional Review Boards at all participating centers (see the Acknowledgments section).

A total of 37 children (ages 4 to 15 y, 11 girls and 26 boys; 18 right/19 left side affected) with primarily spastic hemiplegic UECP (Gross Motor Function Classification System levels 1 or 2) met standard surgical indications for improving forearm, wrist, and thumb position by (1) FCU to ECRB tendon transfer, (2) PT release, and (3) AP release with EPL rerouting. The standard indications were as described in the introduction: (1) deficient active supination; (2) deficient active wrist extension with adequate digital control, and with wrist flexion deformity with FCU as the primary deforming force; and (3) adduction of the thumb ray with flexion at the thumb metacarpophalangeal joint, with inability to make a fist with the thumb outside the flexed digits.[2–5]

Subjects underwent active and passive ROM measurements and stereognosis, AHA, Box and Blocks, and SHUEE testing, (in addition to testing of cognition, dystonia, and 2 measurements of participation not included in this report), as part of a randomized, multicenter controlled trial of treatment, the results of which are reported separately.[14]

Active and Passive ROM Measurement

Active and passive ROM were measured in a standardized manner by occupational therapists who were trained to follow a specific protocol using a script, starting with the elbow and moving on to the forearm, wrist, fingers, and thumb and using a goniometer to measure for each joint first active ROM, followed by passive ROM (Table 1).

Stereognosis Testing

Stereognosis testing involves asking a child to manipulate and identify 12 common objects with the affected hand. One set of objects is placed on the table in front of the child, another set is hidden from view behind a cloth. The child places his/her hand behind the cloth and the assessor places an object in the child's hand and asks the child to identify the object he/she is holding but not seeing based on the items on the table. One point is given for each correctly identified object, so that a higher score indicates better stereognosis; the normal score is 12.[15]

Activity Limitation Measures

AHA is a video-based test where interaction with each of the 22 bimanual test items is graded on a 4-point scale. A score of 4 points requires demonstration of effective and spontaneous use and a score of 1 point indicates ineffective and nonspontaneous use. The scores achieved for all 22 test items are added together to create a sum score, with a maximum of 88.[10] Administration of the AHA requires specialized training; all therapists participating in this study were so trained. A trained therapist administers and scores the AHA in approximately 45 minutes. For the purposes of this study, all therapists were trained in administering the AHA.

TABLE 1. ROM Score Form

Left			Right	
Active	Passive	Range of Motion (deg.)	Active	Passive
		Elbow flexion (0-150)		
		Elbow extension (0)		
		Forearm supination (0-80)		
		Forearm pronation (0-80)		
		Wrist flexion (0-80)		
		Wrist extension (0-70)		
		Wrist ulnar deviation (0-30)		
		Wrist radial deviation (0-20)		
		Thumb CMC palmar ABD (0-70)		
		Thumb MCP flexion (0-50)		
		Thumb MCP extension (0)		
		Thumb IP flexion (0-90)		
		Thumb IP extension (0)		

ABD indicates abduction; CMC, carpometacarpal; IP, interphalangeal; MCP, metacarpophalangeal; ROM, range of motion.

Box and Blocks is a timed test requiring a child seated at a table to transfer as many 1-inch blocks as possible over a 7-inch barrier in 1 minute with 1 hand. The score is the number of blocks transferred. Normal scores vary with age and hand dominance.[11] This test was administered by experienced occupational therapists in a standardized manner, requiring about 10 minutes to perform.

SHUEE is a video-based test where completion of 16 bimanual tasks is measured on 3 scales; one of these, Dynamic Positional Analysis (DPA), was used for the purpose of this study. DPA measures alignment of the elbow, forearm, wrist, thumb, and fingers during performance of 4 tasks used to assess each joint. Higher scores are based on ability to abduct the thumb, extend the wrist, supinate the forearm, and extend the elbow.[13] To calculate the wrist DPA score, the scores achieved for each wrist task are summed and divided by the maximum score possible, then converted to a percentage (multiplied by 100). The elbow DPA is calculated in the same manner using the SHUEE elbow tasks. The total SHUEE DPA is the sum of scores for all 16 SHUEE tasks divided by the maximum score, then converted to a percentage. A higher score reflects better DPA; 100% is the maximum. Although the total DPA score has been validated,[13] the individual alignment scores (eg, wrist DPA score) have not, so they were not considered as independent activity limitation measures for the purpose of data analysis. SHUEE administration and scoring requires specialized training and requires approximately 45 minutes. All participating therapists were trained in administering and scoring the SHUEE.

Statistical Analysis

Spearman rank correlation coefficients were calculated to determine whether standard impairment measures correlated with activity limitation measures. A correlation coefficient (ρ) of 0.50 to 0.75 was considered moderate to good, 0.25 to 0.49 fair, and 0 to 0.24 poor. The level of significance was set at 5% ($P < 0.05$).

RESULTS

Measures of Impairment

Although all subjects had primarily spastic CP and were candidates for surgical reconstruction for UECP based on standard surgical indications, they had a wide range of disease severity as seen in Table 2. Stereognosis ranged from normal to severely impaired (mean of 6, SD = 4, normal = 12). In addition, the SD for active forearm supination was 38 degrees, for active wrist extension 40 degrees, and for thumb radial abduction 18 degrees. No subject had normal active supination, wrist extension, or thumb radial abduction.

Measures of Activity

All subjects had scores reflecting less than full function on all activity limitation measures, including the AHA (mean 53, SD = 9, full function = 88), Box and Blocks (mean 11, SD = 7, normal varies by age[11,12] but all scores were lower than normal values for 4 y olds), and SHUEE DPA (mean 67, SD = 9, maximum = 100) (Table 3).

TABLE 2. Impairment Measures*

	N	Minimum	Maximum	Mean	SD
Stereognosis†	37	1	12	6.1	3.6
Forearm supination‡	37	−90	75	3	38
Wrist extension‡	36	−90	52	−6	40
Thumb CMC radial abduction‡	35	0	45	21	18

*All measurements are for the affected side.
†Stereognosis score = number of objects (hidden from view) the child can manipulate and identify (total = 12).
‡CMC indicates carpometacarpal joint; all measurements are active range of motion, and all are in degrees.

Comparison of Impairment and Activity limitation Measures

Stereognosis was positively correlated with performance on the AHA (ρ = 0.54, $P = 0.001$), but not with Box and Blocks or SHUEE DPA, indicating that children with better stereognosis performed better on the AHA. Active forearm supination was positively correlated with the AHA (ρ = 0.47, $P = 0.003$), indicating that as active forearm supination increased so did the AHA score, and with the SHUEE Forearm DPA (Fig. 1) but not with SHUEE total DPA or Box and Blocks. Active wrist extension was positively correlated with the AHA (ρ = 0.55, $P = 0.001$) and SHUEE total DPA (ρ = 0.41, $P = 0.01$), but only weakly correlated with SHUEE wrist DPA (Fig. 2) and not correlated with Box and Blocks. Thumb radial abduction was not correlated with any of the activity measures, but thumb function was not well visualized on the video-recorded SHUEE and AHA tests.

Of the 12 comparisons between impairment and activity measures, only 4 measures correlated significantly, indicating that the degree of limitation of ROM and stereognosis did not consistently correlate with limitations in hand function as measured by activity measures.

Comparison of Activity Limitation Measures

Performance on the AHA test was positively correlated with performance on Box and Blocks (ρ = 0.63, $P < 0.001$) but not with performance on the SHUEE DPA (ρ = 0.28, $P > 0.05$). Performance on Box and Blocks was positively correlated with performance on SHUEE DPA (ρ = 0.35, $P = 0.04$).

TABLE 3. Activity Limitation Measures (Affected Side)

	N	Minimum	Maximum	Mean	SD
AHA sum (points)	37	34	71	53	9
Box and Blocks (objects)	37	2	27	11	7
SHUEE DPA (deg.)	37	47	86	67	9
Wrist DPA (deg.)	37	1	12	5	2
Forearm DPA (deg.)	37	1	12	5	3

AHA indicates Assisting Hand Assessment; DPA, Dynamic Positional Analyses; SHUEE, Shriners Hospitals Upper Extremity Evaluation.

DISCUSSION

The standard indications for surgical intervention in UECP are not based on a child's ability to complete everyday activities using the affected extremity, despite the existence of tools designed to assess activity. Surgical indications were developed before the advent of these disease-specific activity limitation measures, which may help identify children who are able to accomplish ROM on examination, but do not utilize this ROM to accomplish everyday activities. In practice, surgeons experienced in the care of children with UECP undoubtedly consider functional parameters other than ROM when planning surgical reconstruction, but these additional parameters have not been compared with standard impairment-based indications in a systematic way.

We found inconsistent correlations between standard impairment-based surgical indications and activity measures, and found imperfect correlation between the results of 3 activity limitation measures. Although this study supports the use of the impairment measure of active forearm supination as an indicator for surgery (Fig. 1), it demonstrates that active wrist extension does not correlate with wrist extension during task performance (Fig. 2).

The positive correlation between stereognosis and performance on the AHA test is not surprising as children with impaired stereognosis are less likely to use the affected extremity[15]; the AHA may be more sensitive to this than Box and Blocks or the SHUEE. The role of stereognosis in function is still being established in UECP; this measure is probably best described as an impairment measure (see the Methods section above).

The conclusions of this study are strengthened by the fact that all subjects were children considered to be candidates for reconstructive upper extremity surgery involving PT release, FCU to ECRB tendon transfer, and AP release with EPL rerouting based on standard indications as determined by experienced surgeons, and all testing was administered by trained and experienced therapists in a standardized manner. The main limitation of this study is the heterogeneity of the sampled population, which reflects the complex nature of UECP. As our inclusion criteria for this study were that children were candidates for the specific operations we studied based on standard indications, and as we studied only this particular subgroup of children with CP, we cannot assume that our findings are more widely applicable. Despite this, and the wide spectrum of impairment that CP may cause, the results of the activity limitation measures correlated with each other, although imperfectly.

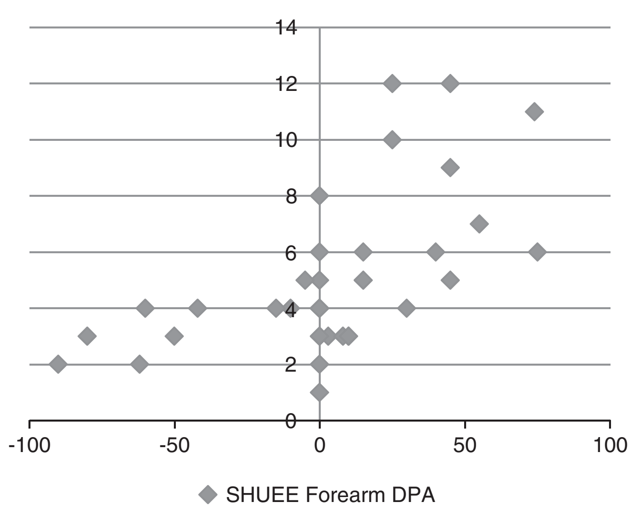

FIGURE 1. Scatterplot of correlation between active forearm supination and SHUEE DPA forearm scores. This shows a strong correlation with $r=0.63$. DPA indicates Dynamic Positional Analyses; SHUEE, Shriners Hospitals Upper Extremity Evaluation.

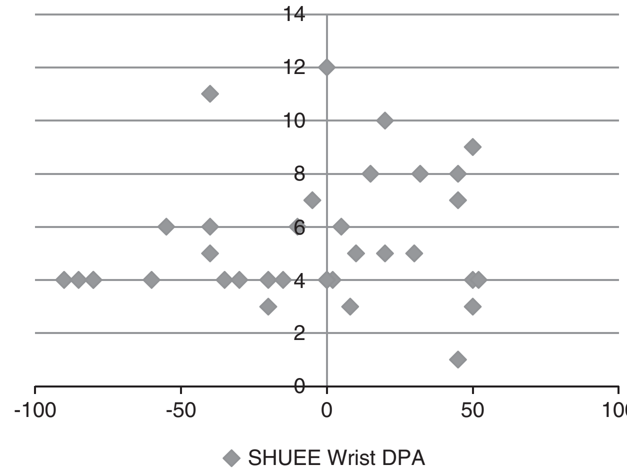

FIGURE 2. Scatterplot of correlation between active wrist extension and SHUEE DPA wrist scores. This shows a weak correlation with $r=0.29$. DPA indicates Dynamic Positional Analyses; SHUEE, Shriners Hospitals Upper Extremity Evaluation.

One goal of surgical intervention in children with UECP is to improve their ability to perform activities using the impaired hand, ultimately enabling them to participate more fully in life situations. Activity limitation measures are surrogate measures of the ability to perform daily activity, and this study shows that they do not consistently correlate with the impairment measures tested, including ROM, the standard indication for surgery. In addition, even though the Box and Blocks correlates with both the AHA and the SHUEE DPA, the AHA and SHUEE DPA did not correlate with each other. The AHA tests spontaneity of grasp and release, but does not specifically examine segmental alignment of the extremity during task performance. Thus a child could conceivably score well on the AHA while exhibiting poor alignment (causing a lower score on the SHUEE). Box and Blocks is a simple indicator of extremity function; a child with better alignment (as measured by the SHUEE) and more spontaneous functioning (as measured by the AHA) would likely be able to transfer more blocks over a barrier in 1 minute, leading to a higher score on the Box and Blocks.

This study does not determine which of these activity tests is best. The Box and Blocks is a well-validated test that is quick and easy to perform and does not require video analysis. However, it tests only grasp and release of blocks with 1 hand. In contrast, the AHA and SHUEE test performance of several more complex bimanual activities. Of these 2, the SHUEE is easier to learn and quicker to perform, but both require at least 45 minutes to administer and analyze, in addition to formal therapist training. It is possible that there is a need for the development of another activity measure that combines the strengths of these 3 tests.

A combination of measures across the spectrum of the WHO ICF will likely provide the best and most appropriate indicators for upper extremity surgery for this population. In addition to measuring ROM, we recommend using Box and Blocks and either the AHA or SHUEE, as preferred by the therapist and surgeon, until additional studies determine whether one of these bimanual function tests is more useful than the other for measuring change in bimanual function after intervention for children with UECP. More work is needed to develop a reliable method of measuring thumb position, as this important aspect of hand function was difficult to visualize on the videotaped tests (AHA and SHUEE).

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