Evaluation of the Capabilities of Upper Extremity Test (CUE-T) in Children With Tetraplegia

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Background: The Capabilities of Upper Extremity Test (CUE-T) is a spinal cord injury (SCI)–specific instrument based on the CUE Questionnaire (CUE-Q). **Objective:** To evaluate the psychometric properties of CUE-T in children with cervical SCI and determine the lowest age appropriate for test administration. **Method:** In this repeated measures multicenter study, 39 youths, mean age 12.3 years and mean time post injury 5.14 years, completed two administrations of the CUE-T. Test-retest reliability, internal consistency, and known groups validity were measured. Concurrent and discriminant validity were measured against previously validated measures: CUE-Q, Graded Redefined Assessment of Strength, Sensibility and Prehension (GRASSP), Spinal Cord Independence Measure (SCIM) III, SCIM III-Self Care (SCIM-SC), and SCIM-Mobility. **Results:** The CUE-T scores demonstrated strong test-retest reliability (ICC $\geq$ 0.95), strong internal consistency ($\alpha \geq 0.90$), and acceptable individual item agreement ($\kappa \geq 0.49$). The hand subscale had better scores ($p < .05$) for the motor incomplete versus complete known groups, and the arm, hand, and side subscales had better scores ($p < .05$) for higher versus lower strength groups. The CUE-T had strong concurrent validity with the CUE-Q ($r = 0.85$-0.87), GRASSP ($r = 0.78$-0.90), and SCIM-SC ($r = 0.70$) and moderate-to-weak correlation with the total SCIM ($r = 0.65$) and SCIM-Mobility ($r = 0.51$). Children older than 6 years with mature grasp patterns were able to complete the CUE-T. **Conclusion:** The CUE-T scores are reliable and valid for use in children with cervical SCI older than 6 years of age. **Key words:** *Capabilities of Upper Extremity Test, pediatric, spinal cord injury, upper extremity*

The need for standardized evaluation of upper extremity (UE) performance comes from the advancements in interventions that have helped realize the functional improvements for individuals living with tetraplegia[1] and the demand for evidence-informed practice.[2] Although notable UE assessments have been described, none have been uniformly adopted for research or clinical use and, until recently, few were designed to evaluate recovery of neurological UE function following spinal cord injury (SCI). However, over the last several years, Kalsi-Ryan and colleagues have developed and validated the Graded Redefined Assessment of Strength, Sensibility and Prehension (GRASSP) for adults with tetraplegia.[3] The GRASSP combines well-established methods of manual muscle strength testing and monofilament sensory testing with observation of grasp and pinch patterns during object manipulation.[3] Although the GRASSP is capable of detecting neurological recovery and change due to interventions, and despite strong psychometric properties,[4] its evaluation of functional hand performance is limited in scope (lateral pinch, three-jaw chuck, palmar grasp). In contrast to the limited performance component of the GRASSP, the Capabilities of Upper Extremity Test (CUE-T) evaluates 19 different performance aspects of UE function, including unilateral, bilateral, proximal, and distal functions.[5] Taken together, the CUE-T items measure observed UE capabilities and have

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demonstrated a high level of reliability.[6] The CUE-T is an SCI-specific instrument developed by Marino and colleagues based on the Capabilities of the Upper Extremity Questionnaire (CUE-Q).[5,7] When used in combination, the CUE-T and CUE-Q provide an objective (CUE-T) and self-perceived (CUE-Q) assessment of UE function necessary for performance of basic and instrumental activities of daily living (ADL).

Given the relevance of the CUE-T items to persons with tetraplegia and preliminary indication of strong psychometric properties in adults, the purpose of this study was to evaluate the reliability of the CUE-T when administered repeatedly in children and to examine if it is a valid indictor of UE function of children with SCI.

Methods

This study was part of a larger multicenter repeated measures study aimed to examine the psychometric properties of instruments used for adult SCI clinical trials in children and youth and to determine the lower age in which the instruments have utility. The methods for the larger study have been described elsewhere[8] and are briefly summarized here.

Children were recruited from seven facilities across the United States and were included if they were <18 years old, had chronic and neurologically stable SCI from traumatic or nontraumatic (transverse myelitis, vascular insult) acquired etiologies, and consented to participate. Children were excluded if they had progressive spinal disease, a preinjury history of musculoskeletal injuries, spina bifida, suspected conversion syndrome, a traumatic brain injury with difficulty understanding test instructions, or were suicidal.

The study protocol was approved by all site Institutional Review Boards, and all guidelines for human subjects' research were followed throughout the study. Following child assent and parental consent, we recorded month/year of birth, gender, ethnicity, race, primary language, hand dominance, schooling, education level, diagnosis (tetraplegia/paraplegia), injury cause, date and severity (American Spinal Injury Association Impairment Scale [AIS]), and neurological level (NL) defined by the International Standards for Neurological Classification of SCI (ISNCSCI).[9] Demographic data were obtained from medical records and participant and/or caregiver interview. Neurological data were also retrieved from the medical record for ISNCSCI examinations within the previous 12 months; if not available, they were performed at the time of enrollment for participants 6 years or older[10] who were developmentally able to attend to the full assessment. There were instances where there was no ISNCSCI available within the past 12 months and one was unable to be performed at time of enrollment. Together, missing values in children younger than 6 years and in subjects where one was not performed resulted in a group with unknown AIS and neurological level data.

Assessments

CUE-T version 1.0

The CUE-T version 1.0 (**Appendix 1**) administered in this study (CUE-T, 1998, 2005, Thomas Jefferson University, PA) has 17 items: six arm items (each arm), nine hand function items (each hand), and two bilateral items. The raw scores for each item are based on one of three types of actions: (1) repetitive actions – number of repetitions completed within a specific time frame; (2) progressive actions – weight moved; (3) timed actions – amount of time required for task completion. The raw scores were then converted to a 5-point scale ranging from 0 to 4, where 0 = *unable/complete difficulty* and 4 = *no difficulty* (**Appendix 1**). The maximum converted subscore for each arm is 24 and for each hand it is 36, yielding a maximum unilateral (arm + hand) converted score of 60. The maximum converted total score (right side + left side + bilateral) is 128.

The CUE-T was administered by a trained physical or occupational therapist twice within 24 hours, separated by at least 1 hour. The 24-hour time frame was chosen to accommodate the participants' schedule and to minimize the likelihood of forgoing the second administration. The participants were seated in their own wheelchair during testing, if they used one. All but two participants completed testing without trunk orthoses. The same rater completed both administrations. Administration

time and scores were recorded on the CUE-T standardized scoring sheet.

CUE-Q version 2.1

The CUE-Q version 2.1 is a 32-item patient-reported assessment of perceived UE functions that evaluates the same constructs (arm, hand, and bilateral function) as the CUE-T.[5] The CUE-Q scores have demonstrated good validity and reliability in adult populations.[11] Each CUE-Q item is scored on a 5-point scale with 0 = *unable/complete difficulty* and 4 = *no difficulty*. The CUE-Q was administered immediately prior to CUE-T and was used to examine the association between actual performance (CUE-T) and perceived performance (CUE-Q).

GRASSP

The GRASSP, described above, was administered for the evaluation of concurrent validity due to increased acceptance in practice and clinical trials.[12] It has strong test-retest reliability in children with SCI.[13]

Spinal Cord Independence Measure (SCIM-III)

The SCIM-III has 19 items and evaluates self-care (SCIM-SC), respiration, bladder and bowel management, and mobility (SCIM-Mobility).[14] It is considered to be the best available SCI gold-standard assessment of ADL.[15] Psychometric properties of the SCIM-III in children have been established.[8] The SCIM-III was administered using a combination of interview questions and observation, and it was used to evaluate the association between CUE-T and ADL performance.

Investigator training and data collection procedures

Training was conducted for site coordinators and data collectors on procedures for data collection, management, and transmission. CUE-T training was provided by one of the senior authors and developer of the assessment (R.M.). Each participating site received the CUE-T manual, training videos, study procedural manual, standardized recording forms, and unique identifiers. Throughout the data collection period (June 2014 through December 2016), bimonthly team conference call meetings were conducted to discuss enrollment, study procedures, data collection and management, and any concerns. Incomplete records were returned to the submitting site for completion; complete records were entered into a secure study specific database.

Analysis

Data were exported to SPSS for analysis (IBM SPSS version 24.0; IBM Corp., Armonk, NY). Data from the first administration were used for all analyses. Mean, standard deviation, and range values were calculated for the right hand, right arm, and right side (arm + hand), left hand, left arm, and left side (arm + hand), and bilateral scores for the entire sample (N = 39); motor complete (AIS A/B) (n = 13) and incomplete (AIS C/D) (n = 19) groups; two age groups (3-6 years [n = 6], 7-17 years [n = 33]); and four strength groups. The strength groups were based on manual muscle test (MMT) scores of items in the GRASSP strength domain. Differences in scores were examined using nonparametric independent sample t tests (AIS, age) and nonparametric one-way analysis of variance (ANOVA; strength) (type I error = 0.05). When available, pediatric values were compared to adult values from the literature to examine the utility of scores across the lifespan.

Test-retest reliability was evaluated using intraclass correlations (ICC [2,k]) with 95% confidence intervals, hypothesized to be strong if >0.75.[16] Individual item agreement was evaluated using weighted kappa (κ) and considered poor with values of <0.40.[16]

Internal consistency was analyzed by correlations for inter-item, item-to-respective side, item-to-total, and Cronbach's alpha. Correlations <0.40 and Cronbach's α <0.70 were considered weak. Cronbach's $\alpha \geq 0.80$ was considered excellent.[16,17] Spearman's correlations (rho) were performed between the right hand and arm scores and left hand and arm scores. Floor and ceiling effects were assessed for hand and arm CUE-T converted scores and for the CUE-T side scores (arm + hand). All score ceiling and floor effects were considered high at >20%.[16]

Concurrent validity was evaluated by Pearson product-moment correlation (r) of the combined (right total + left total + bilateral total) and side (arm + hand) CUE-T scores against the CUE-Q combined and side scores, GRASSP (strength [right and left, respectively], prehension performance [right and left, respectively], and prehension ability [right and left, respectively]), and SCIM-SC. Concurrent validity of the CUE-T hand component was assessed by Spearman's correlation with the GRASSP prehension performance domain. Discriminant validity was evaluated with the SCIM-III total and SCIM-Mobility subscores.

In order to establish the lower age limit in which the test scores have validity, we examined item agreement, administrator comments, and screen failure reasoning. If an individual was excluded or unable to complete certain items, the comments were evaluated to determine if the exclusion was related to age and/or development.

Results

A total of 57 children with tetraplegia were screened and 18 were excluded. Reasons for exclusion were as follows: 1 (6%) legal guardian was unable to consent due to difficulty speaking and understanding English, 4 (22%) had complete injuries without any movement below the neck, 5 (28%) could not follow instructions due to young developmental age, and 8 (44%) declined participation.

A total of 39 participants with a mean age of 12.3 years (range, 3-17) and mean time since injury of 5.14 years (range, 3 months to 17.2 years) were consented and enrolled. The majority were male (n = 24), Caucasian (n = 33), and identified as non-Hispanic (n = 30) (**Table 1**). There were more participants with motor incomplete injuries (49%) than complete (34%), and 7 (18%) participants had unknown AIS scores. The second administration of the CUE-T by the same rater was completed for 27 of the 39 participants (69%). There were no statistically significant differences in sample characteristics between the first and second administration.

Mean CUE-T scores are shown for the entire sample (N = 39) in **Table 2**, with adult values provided for comparison (R. Marino, unpublished data).[6] The administration time was statistically significant ($p < .05$) between the first CUE-T administration (n = 34; mean = 45.47 minutes; range, 15-86) and the second (n = 26; mean = 39.12 minutes; range, 10-70 minutes).

When examined by AIS (**Appendix 2**), those with motor incomplete (AIS C/D) (n = 19) injuries had higher (better) CUE-T right and left hand subscores, but no statistically significant differences in arm or bilateral subscores. There

Table 1. Demographic characteristics of participants for CUE-T trial one and trial two

	Trial one (n=39)	Trial two (n=27)
	n (%)	n (%)
Age group, years		
3-6	6 (15)	4 (15)
7-17	33(85)	15 (85)
Gender		
Male	24 (62)	19 (70)
Female	15 (39)	8 (30)
Race		
Caucasian	33 (85)	21 (78)
Asian	1 (3)	1 (4)
African American	3 (8)	3 (11)
Other	2 (5)	2 (7)
Ethnicity		
Hispanic	9 (23)	7 (26)
Non-Hispanic	30 (77)	20 (74)
Neurological level grouping		
C1-C5	23 (59)	18 (67)
C6	3 (8)	1 (4)
C7	3 (8)	2 (7)
C8-T1	3 (8)	1 (4)
Unknown	7 (18)	5 (19)
AIS classification		
A	10 (26)	6 (22)
B	3 (8)	3 (11)
C	9 (23)	5 (19)
D	10 (26)	8 (30)
Unknown	7 (18)	5 (19)

Note: AIS = American Spinal Injury Association Impairment Scale; CUE-T = Capabilities of Upper Extremity Test.

Table 2. CUE-T values from first administration and adult values for comparison

CUE-T		Score possible range	Pediatric sample (*n*=39)			Adult sample (*n*=50)		
			M	*SD*	Range	*M*	*SD*	Range
Right	Side	0-60	29.5	15.8	0-59	41.7	14.4	0-57
	Arm	0-24	15.8	6.9	0-24	18.7	4.2	0-24
	Hand	0-36	13.8	10.4	0-35	22.7	11.8	0-36
Left	Side	0-60	27.7	15.1	0-53	41.0	16.0	0-58
	Arm	0-24	14.7	6.9	0-24	18.6	4.8	0-24
	Hand	0-36	13.0	9.6	0-33	22.4	12.5	0-36

Note: Total right side = right arm + hand subscores. Total left side = left arm + left hand subscores. CUE-T = Capabilities of Upper Extremity Test.

were statistically significant ($p < .05$) differences across all CUE-T subscales between the levels of strength based on MMT scores (**Table 3**). The groups with more arm strength had better CUE-T scores.

The combined and subscale CUE-T scores showed excellent test-retest reliability (ICC > 0.95) and were statistically significant ($p < .05$). The individual item agreement (**Table 4**) was strong for most items with weighted kappa values ranging from 0.49 to 0.96 on the right side and 0.65 to 0.93 on the left side.

Cronbach's alpha values were excellent for the combined score and subscores ($\alpha \geq 0.90$). Inter-item correlations ranged from 0.04 to 0.90. Individual item correlations with the respective side scores and combined score were adequate for all items (right side, 0.60-0.79; left side, 0.51-0.75; total, 0.44-0.77) indicating strong internal consistency for the scale. The CUE-T side, arm, and hand subscores were distributed throughout the possible range with negligible floor and ceiling effects (<20%).

Table 5 shows correlation coefficients for the CUE-T and corresponding measures. As hypothesized, the CUE-T demonstrated strong positive correlations with the CUE-Q, GRASSP, and SCIM-SC. As hypothesized, CUE-T showed moderate-to-weak correlation with the SCIM-III total score and SCIM-Mobility.

There were only six participants in the lowest age group (3-6 years): two 3-year-olds, one 5-year-old, and three 6-year-olds. Their mean completion time for trial one was 44 minutes (range, 20-78). All children in this group were able to attempt each test item but did not complete all items, in part due to their young age. There were five children (ages 1.5, 3, 4 [$n = 2$], and 5 years) who were excluded from participation, because they were too young developmentally to follow instructions, complete test items, maintain attention to task, or inability to complete an item due to the participants' physical size.

Discussion

The results of this study support the use of the CUE-T with youth with SCI older than 6 years. CUE-T scores had overall strong test-retest reliability, strong internal consistency, and acceptable individual item agreement. Despite having a wide range of administration times, the CUE-T demonstrated relatively good content range and the ability to differentiate between known groups. The CUE-T scores had strong concurrent and discriminant validity when examined against other standard SCI measures.

When compared to adult values, the pediatric CUE-T scores had lower means (less function) for every score. This most likely is attributed to the adult sample's equal distribution across the level of injury (C2-C5, $n = 12$; C6, $n = 11$; C7, $n = 11$; C8-T1, $n = 5$; T2-T6, $n = 11$) and more motor incompletes across all but one (C6) level of injury groups.[6]

Administration time is an important aspect of clinical utility when selecting a measure, particularly in children. Like many performance-based measures, the wide range of administration

Table 3. CUE-T distribution of scores from the first administration between groups based on upper extremity strength calculated from manual muscle test (MMT) scores

CUE-T		Any elbow flexion with all other MMT scores ≤2 (right, *n*=4; left, *n*=3)			Any elbow flexion and wrist extension grade ≥3 with all other MMT scores ≤1 (right, *n*=1; left, *n*=5)			Any elbow flexion and wrist extension grade ≥3 and triceps and/or finger extension grade ≥2 (right, *n*=6; left, *n*=1)			Any elbow flexion and wrist extension grade ≥3 and triceps and/or finger extension grade ≥2 with any finger/thumb flexion (right, *n*=23; left, *n*=21)		
		M	*SD*	Range	*M*	*SD*	Range	*M*	*SD*	Range	*M*	*SD*	Range
Right	Side	5.25	9.18	0-19	18.00	n/a	n/a	27.83	8.93	15-40	36.30	13.77	4-59
	Arm	4.25	7.85	0-16	18.00	n/a	n/a	17.67	3.50	12-22	17.87	5.58	3-24
	Hand	1.00	1.41	0-3	0.00	n/a	n/a	10.17	7.19	3-20	18.43	9.73	1-35
Left	Side	11.00	11.14	1-23	16.20	7.92	4-25	22.00	n/a	n/a	37.86	10.11	15-53
	Arm	6.67	4.93	1-10	12.00	5.52	3-17	18.00	n/a	n/a	18.62	3.89	10-24
	Hand	4.33	7.51	0-13	4.20	4.09	0-9	4.00	n/a	n/a	29.24	7.61	2-33

Note: CUE-T = Capabilities of Upper Extremity Test; n/a = not applicable.

Table 4. Weighted kappa coefficients of CUE-T items between trial one and trial two

	Pediatric sample		Adult sample[6]	
	Right	**Left**	**Right**	**Left**
Reach forward	0.84	0.88	0.69	0.66
Reach up	0.79	0.76	0.73	0.66
Reach down	0.78	0.79	0.68	0.67
Push weight	0.95	0.93	0.74	0.77
Pull weight	0.76	0.77	0.91	0.91
Wrist up	0.88	0.86	0.59	0.62
Grasp dynamometer	0.87	0.85	0.80	0.85
Pinch die (2 finger)	0.49	0.65	0.68	0.81
Pencil (3 finger)	0.79	0.79	0.72	0.82
Key pinch	0.88	0.88	0.90	0.93
Wide grasp	0.95	0.85	0.90	0.94
Manipulate	0.85	0.76	0.90	0.83
Push index finger	0.83	0.67	0.76	0.79
Push with thumb	0.86	0.77	0.83	0.79
Acquire/ Release	0.96	0.93	0.85	0.91
	Bilateral			
Lift up weight	0.88		0.78	
Push down	0.83		0.84	

Note: CUE-T = Capabilities of Upper Extremity Test.

times for CUE-T (10-86 minutes) was likely due to participants' varied capacity to complete the items. Despite no statistical differences in sample characteristics, trial two required significantly less time to complete than trial one, indicating a potential increase in children's understanding and/or a practice effect. In this study, time between repeated trials was short (60 minutes to 24 hours) to maximize the likelihood of successfully completing trial two in an outpatient environment. In future studies that assess test-retest reliability, this time interval could be between 2 days to 2 weeks,[18] enough to minimize practice effect and ensure stability of function, assuming enrollment of youth with chronic and stable injuries. Importantly, the CUE-T was developed to take no more than 60 minutes of administration time.[5] Since the CUE-T took over an hour in several (n = 7) participants in this study, future work should evaluate the completion time for each item and time-consuming items should be modified accordingly.

As anticipated, the wide range of correlation values for inter-item, item-to-side, and item-to-total scores indicate that some items do not correlate, which is reflective of items' abilities to capture UE function in different domains such as proximal and distal functions. For example, the low correlation between reach forward and grasp dynamometer (0.04) was expected as there is a large degree of difference in their constructs. Reach forward intends to determine how far in front of the body a person can get their hand at shoulder level, whereas the grasp dynamometer aims to determine if a subject can acquire and maintain an object using cylindrical grasp.

The CUE-T's lack of ability to consistently distinguish between motor complete and incomplete tetraplegia indicates the influence of small sample size, but it may also be due to true similarities of arm function between groups. Larger sample sizes would enable stratification into neurological levels and hand classification.[19] Both of these could be important parameters for known group differences. However, despite small sample size, the CUE-T differentiated between groups based on UE strength. This indicates that this an effective instrument at capturing strength-based functional performance for the arm and hand in children with tetraplegia.

The CUE-T's strong association with the CUE-Q was to be expected as it was developed directly from the CUE-Q and has the same constructs. It also indicates a strong relationship between performance-based and self-reported assessment for the UE that can add valuable information to the comprehensive assessment of an individual. Strong correlation with the impairment-based GRASSP scores provides further evidence that the CUE-T is a valid indicator of hand function. As hypothesized, the SCIM-SC subscale was strongly correlated with the CUE-T, likely due to the reliance on the UE to complete SCIM-SC items. The SCIM-III is not a measure solely focused on UE capability but rather assesses several functional

Table 5. Concurrent and discriminant validity of the CUE-T scores: Trial one data.

CUE-T	CUE-Q (total, right, left)		GRASSP Strength (right, left)	GRASSP Prehension Performance (right, left)	GRASSP Prehension Ability (right, left)	SCIM-III Total	SCIM-III SC		SCIM-III Mobility	
	Pediatric sample	*Adult sample*					*Pediatric sample*	*Adult sample*	*Pediatric sample*	*Adult sample*
Total	0.846	0.822				0.65	0.704	0.695	0.512	0.55
Right Side	0.848		0.888	0.902	0.834					
Left Side	0.871		0.857	0.875	0.779					

Note: All pediatric results significant at the $p = .01$ level. CUE-T = Capabilities of Upper Extremity Test; GRASSP = Graded Redefined Assessment of Strength, Sensibility and Prehension; SCIM-III = Spinal Cord Independence Measure III.

domains. The lower correlation between the CUE-T and total SCIM-III and SCIM-Mobility indicates good discriminant validity, indicating that the difference between the mobility and UE constructs is well captured. Overall, these correlations mirror those in the adult literature and support the CUE-T as a validated measure that can be used across the lifespan.[6]

To our knowledge, this is the first study to evaluate the CUE-T in individuals younger than 17 years of age.[6] While we successfully administered the CUE-T to six children who were 6 years of age and younger, there were five children (ages 1.5, 3, 4 [$n = 2$], and 5 years old) who were excluded due to inability to understand and/or remain engaged for the length of the test. The low item reliability in this sample for the 2-finger pinch (right, $\kappa = 0.51$; left, $\kappa = 0.65$) was further analyzed and showed that the 3- to 6-year-olds had lower item reliability (right, $\kappa = -0.11$; left, $\kappa = 0.56$) than the 7- to 17-year-olds (right, $\kappa = 0.59$; left, $\kappa = 0.64$). This can be attributed to immature pinch grasp in children ages 3 to 6.[20] In addition, the three CUE-T items (2-finger pinch, 3-finger pinch, key pinch) require full development of intrinsic hand function and in-hand manipulation skills, which may not be developed even in typically developing children until 7 years of age.[21,22] For this reason, we suggest that the CUE-T be used in children older than 6 years.

Limitations

The small sample size, overall and in each of the known groups, limited our ability to evaluate the psychometric properties as a function of AIS within each NL group. Moreover, a relatively large number ($n = 7$) did not have complete ISNCSCI examinations prior to enrollment. We excluded these participants in our known groups analysis, further reducing the sample for analysis. We also did not record which participants had an ISNCSCI at the time of study enrollment versus obtaining it from the medical records. The short duration of 24 hours between the two trials may have led to fatigue or practice effects and subsequently altered the performance during the second examination.

Conclusion

This study provides evidence in support of the validity and reliability of CUE-T scores to assess children with SCI older than 6 years of age.

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APPENDIX 1

CUE-T Items and Scoring

Arm	Raw scoring	Score conversion	Hand	Raw scoring	Score conversion	Bilateral	Raw scoring	Score conversation
Reach forward	Number of repetitions in 30 seconds	0= cannot complete 1= partial completion of 1 repetition 2= 1-15 repetitions 3=16-30 repetitions 4=31+ repetitions	Grasp dynamometer	Mean grasp strength of 3 trials measured in kilograms	0=0 kg 1=0.1-3.0 kg 2=3.1-10.0 kg 3=10.1-20.0 kg 4=20.1+ kg	Lift up weight	Based on amount of weight lifted: ½ kg – 2 kg	0=cannot complete 1=lifts empty 2=lifts ½ kg 3= lifts 1 kg 4= lifts 2 kg
Reach up	Number of repetitions in 30 seconds	0= cannot complete 1= partial completion of 1 repetition 2=1-16 repetitions 3=16-25 repetitions 4=26+ repetitions	Pinch die (two-finger grasp)	Number of repetitions in 30 seconds	0= cannot complete 1= partial completion – 2 repetitions 2=3-5 repetitions 3=6-8 repetitions 4=9+ repetitions	Push down	Based on duration of weight shift: 0-30 seconds	0=cannot complete 1=0.1-4.9 seconds 2=5.0-14.9 seconds 3=15.0-29.9 seconds 4=30 seconds
Reach down	Number of repetitions in 30 seconds	0= cannot complete 1= partial completion of 1 repetition 2=1-10 repetitions 3=11-15 repetitions 4=16+ repetitions	Pencil (three-finger grasp)	Number of repetitions in 30 seconds	0= cannot complete 1= partial completion – 2 repetitions 2=3-5 repetitions 3=6-8 repetitions 4=9+ repetitions			
Pull weight	Based on weight moved: 0 kg- 4 kg	0= cannot complete 1=move ½ kg 2=moves 1 kg 3=moves 2 kg 4=moves 4 kg	Key pinch	Mean pinch strength of 3 trials measured in kilograms	0= cannot pinch a credit for at least 5 seconds & 0 kg 1= can pinch a credit card for 5 seconds & 0 kg 2=0.1-2.0 kg 3=2.1-5.0 kg 4=5.1+ kg			
Push weight	Based on weight moved: as above	0= cannot complete 1=move ½ kg 2=moves 1 kg 3=moves 2 kg 4=moves 4 kg	Wide grasp	Based on amount of weight lifted and time held give range of weight and time	0=cannot complete 1= lift empty 2=lift ½ kg for <5 seconds 3=lift ½ kg for 5 seconds 4=lift 1 kg for 5 seconds			

(*Continued*)

(CONT.)

Arm	Raw scoring	Score conversion	Hand	Raw scoring	Score conversion	Bilateral	Raw scoring	Score conversation
Wrist up	Number of repetitions in 30 seconds	0=cannot complete 1=partial completion of 1 repetition 2=1-20 repetitions 3=21-35 repetitions 4=36+ repetitions	Manipulate washer	Number of revolutions in 30 seconds	0=cannot complete 1=partial completion of 1 revolution 2=1-5 revolutions 3=6-10 revolutions 4=11+ revolutions			
			Push with index finger	Based on time to complete: 0-90 seconds	0=cannot complete 1=20.1-90 seconds 2=10.1-20 seconds 3=7.1-10 seconds 4= ≤7.0 seconds			
			Push with thumb	Based on time to complete: 0 – 90 seconds	0=cannot complete 1=20.1-90 seconds 2=10.1-20 seconds 3=7.1-10 seconds 4= ≤7.0 seconds			
			Acquire/ Release (of grasp dynamometer and container)	Based on ability to acquire and release (yes or no, acquire; yes or no release)	Number of yes (0-4)			

Note: CUE-T = Capabilities of Upper Extremity Test.

APPENDIX 2

CUE-T Distribution of Scores of Trial 1 for Motor Complete (AIS A/B) and Incomplete (ASI C/D) Injuries and Two Pediatric Age Groups

CUE-T		Motor complete (*n*=13)			Motor incomplete (*n*=19)			3-6 year olds (*n*=6)			7 – 17 year olds (*n*=33)		
		M	***SD***	**Range**	***M***	***SD***	**Range**	***M***	***SD***	**Range**	***M***	***SD***	**Range**
Right	Side	22.9*	14.0	0-50	35.3*	14.1	1-52	25.83	16.20	4-45	30.21	15.86	0-59
	Arm	14.5	6.8	0-22	17.2	6.7	0-24	14.17	6.94	4-22	16.06	7.00	0-24
	Hand	8.4*	9.2	0-32	18.1*	8.9	1-30	11.67	9.65	0-23	14.15	10.68	0-35
Left	Side	22.9	15.3	0-47	31.3	15.9	2-53	26.17	17.70	2-45	28.00	14.91	0-53
	Arm	13.8	6.8	0-21	15.6	7.4	1-24	12.67	9.05	2-23	15.10	6.59	0-24
	Hand	9.1*	9.7	0-28	15.7*	9.9	0-33	13.50	9.14	0-24	12.91	9.80	0-33
Bilateral		2.8	2.9	0-8	4.4	3.6	0-8	0.83*	1.17	0-3	3.94*	3.16	0-8

Note: CUE-T = Capabilities of Upper Extremity Test.

*Between group difference is significant at $p < .05$.