Original Research

Construct Validity of a Task-Oriented Bimanual and Unimanual Strength Measurement in Children With Unilateral Cerebral Palsy

Mellanie Geijen, Eugene Rameckers, Caroline Bastiaenen, Andrew Gordon, Rob Smeets

Objective. The purposes of this study were to (1) investigate aspects of construct validity of peak force measurements of crate-and-pitcher tasks using the Task-oriented Arm-hAnd Capacity (TAAC), an instrument designed to measure task-oriented arm and hand strength for cross-sectional and evaluation purposes, and (2) compare TAAC measurements with those of comparative measures using COSMIN guidelines.

Methods. In this cross-sectional validity study, participants were 105 children (mean age = 12 years 10 months; number of boys = 66) diagnosed with unilateral cerebral palsy (UCP). Ten a priori hypotheses were formulated with peak force of the TAAC as index measure and compared with measures on body functions and structure and activity level of the International Classification of Functioning, Disability and Health for Children and Youth. Strength and direction of the relationship between the TAAC and comparative measures were investigated by calculating Pearson correlation coefficients (r).

Results. On body functions and structures level, low-to-moderate positive correlations (0.493–0.687) were found. On activity level, low negative and positive correlations (−0.271 to 0.387) were found.

Conclusion. The construct of peak force measurement of the TAAC is in line with the a priori hypotheses with comparators on body function and structures and activity level, indicating a partial overlap of the construct of the TAAC with both International Classification of Functioning levels. The TAAC appears to be valuable, as it measures functional strength that differs from the constructs of the comparators. More research with a larger population and more comparators is needed.

Impact. Clinically relevant information is lacking about the use of strength and strength measurement during daily activities in children with UCP. This study shows that the TAAC provides unique information about functional strength in children with UCP.

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Children with unilateral cerebral palsy (UCP) experience difficulties in performing activities of daily living (ADL) due to upper limb dysfunction.[1] Due to central neurological disorders, children with cerebral palsy (CP) experience multiple problems, such as spasticity, impaired selectivity, muscle weakness, and impaired anticipatory control.[2,3] These impairments are major causes of poor arm-hand skill performance, defined as "use of arm and hand during ADL-tasks."[4] The lack of muscle strength is one of the key problems in performing ADL tasks, and assessing this strength during the performance of such ADL tasks is highly relevant for the proper selection and evaluation of treatment.[2,5] For this, a measure with good clinimetric properties for this particular population is needed.[2,5]

Rehabilitation is aimed to improve motor function, so for children with CP the aim is to increase the ability to perform activities and become more independent. During therapy, the focus is to improve muscle strength by strength training.[6] Therefore, upper limb muscle strength commonly is assessed before and after therapy to determine change in strength.[6] Most frequently, maximal voluntary contraction of a muscle is measured using grip and pinch strength measurement or isometric measurement with hand-held dynamometry.[7,8] Currently, functional therapy is the most promising evidence-based therapy in children with UCP.[9] During this therapy, individual needs, related goals, and relevant and meaningful tasks are trained.[10] Training of meaningful tasks is referred to as "task-oriented training," and if strength needs to be trained, it should be integrated into this training.[10,11] Task-oriented strength training focuses on generation of strength during performance of an ADL task, in which, consequently, most relevant muscle groups for a particular ADL task are trained, instead of an isolated muscle group.[4] To evaluate whether task-oriented training is successful, strength needed to execute such specific ADL tasks should be measured as an essential outcome measure. This is important as proper assessment regarding factors (eg, muscle weakness during performance) that affect performance of ADL tasks will improve the selection of treatment.

As no measure was available to measure task-oriented upper limb strength, we recently developed a measure based on this specific concept: Task-oriented Arm hAnd Capacity (TAAC) instrument.[12] The TAAC measures peak force while the child performs an ADL task. Information about the strength while performing an ADL task allows the therapist to make an adequate analysis about the quality and success of the performance of an ADL task. This information supports the therapist in formulating adequate treatment content. Furthermore, in a later stage, task-oriented strength after therapy can be evaluated. In a previous study, the TAAC demonstrated moderate to good test–retest reliability.[12] Another important aspect in the development of new instruments is construct validity. In this study, cross-sectional construct validity of 2 grasp and lift tasks are investigated. Due to lower grip strength, lack of selectivity, and a decrease in anticipatory control of the execution of tasks, children with UCP particularly experience problems with movements such as grasping and lifting.[4,13,14] Lemmens et al[4] identified which movement components were present in relevant ADL tasks for children with CP. The results showed that movement components such as grasping, holding, and lifting were rated as the most prominent movement components. Based on this research, a crate and pitcher task were chosen for the development of the ADL tasks of the TAAC. These tasks represent a uni- and bi-manual task and consists of the movement components grasping, holding, and lifting. Peak force measured with the TAAC is the maximal task-oriented strength generated during the performance of an activity.

More often, measurements are linked to the International Classification of Functioning, Disability and Health for Children and Youth (ICF-CY) framework, which consists of body function and structures, activity, and participation, and includes personal and environmental factors. The framework of the International Classification of Functioning (ICF) is meant to describe and classify health. The theoretical construct of a measure can be linked to 1 of the levels of the ICF-CY to understand and interpret the role of a measure in describing specific aspects of health in a population better. It also could be that an overlap of the construct within the measure with more than 1 level of the ICF is the most appropriate linkage.[15] Within the context of the ICF-CY, we linked the construct of the TAAC to both body function and structures and activity level. The crate and pitcher task of the TAAC are linked to measure constructs "strength" and "selectivity" (to execute an activity with precision) within the body function and structures level; and "capacity of lifting a crate bimanually," "capacity of lifting a pitcher unimanually," and "manual skills" are within the activity level.

To accurately measure a child's task-oriented upper limb strength during a relevant ADL task, sufficient clinimetric properties of the instrument, that is, reliability, validity, and responsiveness, are needed. We previously investigated test–retest reliability of peak force measurements of bimanual crate and unimanual pitcher tasks of the TAAC in children with UCP.[12] Results showed high test–retest reliability for the crate and pitcher task with the non-affected hand (NAH) and a moderate test–retest reliability for the pitcher task with the affected hand (AH).[12] In the current study, aspects of construct validity of the peak force measurement of the crate and pitcher task of the TAAC are investigated according to the COnsensus-based Standards for the selection of health Measurement INstruments (COSMIN) guidelines.[16] Outcomes of the TAAC are compared with outcomes of other measures selected for this purpose. The theoretical constructs of those measures are hypothesized to be more

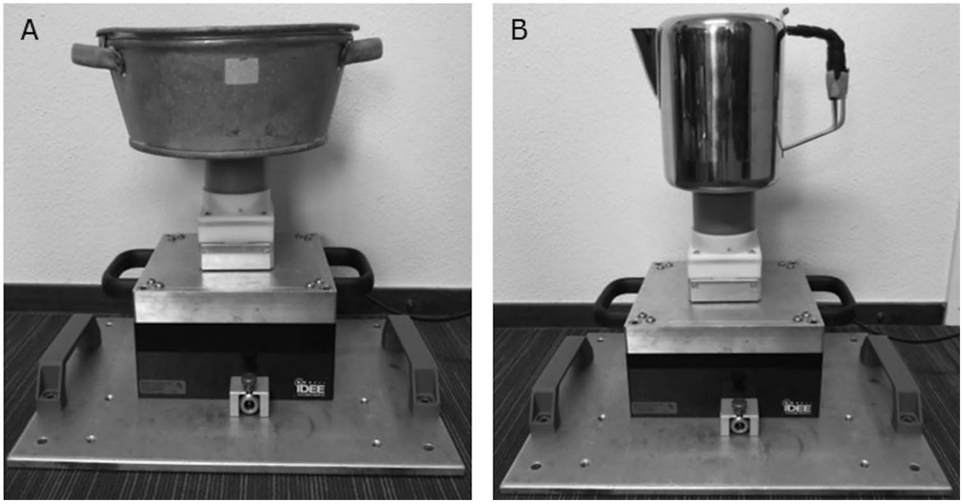

Figure 1.
The Task-oriented Arm-hAnd Capacity (TAAC) instrument with the crate attached (A) and the pitcher attached (B).

or less related to the theoretical construct of our new instrument. A priori hypotheses were developed based on the expected level of agreement of the theoretical constructs of these measures compared with the theoretical construct of the peak force measurement of the TAAC. Theoretical constructs of both index and comparator measures are considered within the framework of the ICF-CY domains: body function and structures and activity.

Methods

Design and Participants

This study is a cross-sectional validity study with peak force of the TAAC as the index measure and maximal peak grip strength (Biometrics, E-Link), Jebsen-Taylor Hand Function Test (JTHFT), Observational Skills Assessment Score (OSAS), ABILHAND-kids, and the Canadian Occupational Performance Measure (COPM) as comparators. Data were obtained during 3 different studies, which took place in Adelante (the Netherlands, 2018–0349), Teachers College, Columbia University (NY, USA, 13–220), and a Dutch multicenter study (TOAST-CP, NL49818.015.14). After being informed, children and/or parents of all studies signed an informed consent form with permission to use data for this study. This study was approved by the Medical Ethical Committee of Maastricht University Medical Centre (2018–0349). Children were included if they were 6 to 18 years old, diagnosed with UCP, level I, II, III of the Gross Motor Function Classification System and Manual Ability Classification System, and level I, II, IIb of the Zancolli classification.

Index Measure

The TAAC consists of a measuring unit and attachable objects, such as the crate and pitcher. By attaching the crate or pitcher to the measuring unit, the peak force generated by the participant during the task is measured. More information about measurement properties of the TAAC can be found in Figures 1 and 2.

During the bimanual measurement of the crate task, the participant has to pull the crate fixed to the device straight up with maximal effort and hold it horizontally for 5 seconds. This is repeated 3 times, with 30 seconds rest in between. The child has to gradually build up his/her force and then pull as hard as possible for 5 seconds. During the 5-second hold period, the isometric peak force generated by the arms is measured. Because of technical limits of measurement, no compensatory strategies, such as keeping the arms by his/her side or leaning backwards or forwards or to 1 side could be allowed. To prevent these strategies, the assessor stands next to the participant to check and control the execution of the task. Two additional attempts are allowed if the first measurement fails, that is, if the crate cannot be kept horizontal for the full 5 seconds or if compensatory strategies are used. The same protocol is used for the unimanual measurement with the pitcher. This measurement is performed with the NAH first and then with the AH.

In a previous study, the peak force measurement of the crate task showed high test–retest reliability for children and youth with UCP ($n = 105$; intraclass correlation coefficient (ICC) = 0.955 [6–12 years], ICC = 0.846 [13–18 years]).[12] Peak force measurement of the pitcher task performed with the NAH also showed high test–retest reliability (ICC = 0.902 [6–12 years], ICC = 0.853 [13–18 years]), while for the AH the pitcher task showed moderate test–retest reliability (ICC = 0.586 [6–12 years], ICC = 0.742 [13–18 years]).[12]

The **Task-oriented Arm-hAnd Capacity (TAAC)** instrument (H.12EXTI09881; IDEE, Maastricht, The Netherlands) is an experimental prototype used for research, and will be a part of the newly developed Activities of Daily Life-Test and Training Device (ADL-TTD). The TAAC consists of a measuring unit and attachable objects, such as a crate (0.687 kg) (figure 1A) and a pitcher (0.533 kg) (Figure 1B). By attaching a crate or pitcher to the measuring unit, the force generated by the participant during the task is measured. The TAAC allows pushing and pulling and registers the generated force from -400 till 400 Newton (N), with an accuracy of 1 N. The TAAC is connected to a laptop with the associated software; SENSIT Test and Measurement. The program plots force generated by the participant and stores the data for subsequent export to Excel. The task-oriented strength is expressed as peak force (N) lifted or pushed during the task. Before each measurement with a different task the TAAC needs to be calibrated.

Figure 2.
Measurement properties of the Task-oriented Arm-hAnd Capacity (TAAC).

Comparators

Comparative measures at body function and structures level were maximal peak grip strength as well as JTHFT, OSAS, ABILHAND-kids, and COPM at activity level. These comparators were already chosen in the 3 different studies. Information about the purpose/theoretical construct of the measures and their clinimetric properties can be found in the Supplementary Table.

Peak force of the TAAC was compared with maximal peak grip strength since both instruments measure maximal voluntary contraction and therefore have a common underlying construct "strength." However, the TAAC measures strength while the child performs an ADL task, which increases the functional component compared with the grip strength measurement in which the child is simply squeezing the dynamometer. Peak force of the TAAC is compared with outcomes of the grip strength of both the AH and NAH since it is not known whether correlations differ between both hands.

At activity level, peak force measurement of the TAAC and JTHFT are hypothesized to have different constructs. The TAAC measures strength while performing an ADL task, and JTHFT measures speed of performing fine motor task-oriented activities. Although both measures are hypothesized to have different constructs, selective arm and hand movements are needed to perform both of the tests. Therefore, both measures have underlying construct "selectivity." In the TAAC, the outcome is assessed by strength and in JTHFT by speed. Peak force of the TAAC is compared with outcomes of the JTHFT of both the AH and NAH, since it is not known whether correlations differ between both hands. Furthermore, outcomes of peak force measurement of the TAAC were compared with outcomes of OSAS and ABILHAND-kids both measuring the construct "manual skills." OSAS measures the amount of use of the AH (capacity) of children to perform a standardized bimanual task, whereas ABILHAND-kids measures the performance of children to perform manual skills in a natural environment. The TAAC also measures capacity of generating strength while performing the crate or pitcher task. Peak measurement of the TAAC was also compared with the COPM. The COPM is hypothesized to have a largely different construct compared with the peak force measurement of the TAAC. Data of the COPM were not collected while performing an activity but rather before the start of therapy by interviewing parent(s) regarding child relevant activities in which 1 or both upper extremities are involved. The COPM is quantified within aspects of performance of the selected activity and satisfaction with the performance of that activity. These elements are not measured with the other measures. So, for each child, different activities involving the upper extremities could be identified.

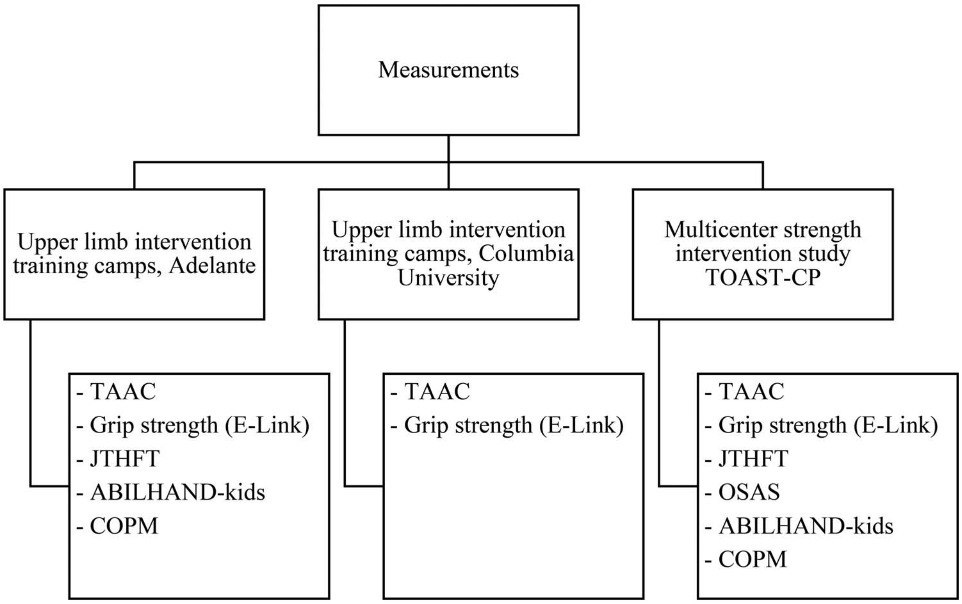

Figure 3.
Flowchart of all measurements. COPM = Canadian Occupational Performance Measure; JTHFT = Jebsen-Taylor Hand Function Test; OSAS = Observational Skills Assessment Score; TAAC = Task-oriented Arm-hAnd Capacity.

Procedures

In the 3 separate studies, measurements were performed during 1 cross-sectional measurement point in time at the same day. A flowchart of the measurement batteries of all studies and the number of children participating and number of collected data of each measurement are presented in Figure 3. Because there is no complete data set for the entire study population on all comparators, the numbers of the collected data of each measurement were added.

Measurements were conducted by 3 assessors, all of whom have a minimum of 2 years of experience conducting these measurements. All assessors used the same standardized protocol. Outcomes of the comparators were collected independently of the TAAC.

Data Analysis

Statistical analyses were performed using SPSS version 23 (SPSS Inc., Chicago, IL, USA). Descriptive statistics were used to characterize the study population. Distribution of scores of all measures was investigated in terms of mean, SD, median, minimal, and maximal score. Floor and ceiling effects were checked through visual inspection of histograms. To investigate strength and direction of the relationship between the index measure and comparative measures based on preset hypotheses, Pearson correlation coefficients (r) were calculated. The peak measurement of the TAAC was considered to have a good validity compared with the other measures when 80% of the hypotheses were supported.[16]

The following hypotheses were formulated at body function and structures level:

1. Peak force measurement of the crate task of the TAAC is expected to have a moderate positive correlation (0.30–0.70) with the maximal peak grip strength of the AH.
2. Peak force measurement of the crate task of the TAAC is expected to have a moderate positive correlation (0.30–0.70) with the maximal peak grip strength of the NAH.
3. Peak force measurement of the pitcher task of the TAAC with the AH is expected to have a moderate positive correlation (0.30–0.70) with the maximal peak grip strength of the AH.
4. Peak force measurement of the pitcher task of the TAAC with the NAH is expected to have a moderate positive correlation (0.30–0.70) with the maximal peak grip strength of the NAH.

The following hypotheses were formulated at activity level:

1. Peak force measurement of the pitcher task of the TAAC with the AH is expected to have a low to moderate positive correlation (0.20–0.50) with the total number of seconds to complete all sub tests of the JTHFT performed with the AH.
2. Peak force measurement of the pitcher task of the TAAC with the NAH is expected to have a low to moderate positive correlation (0.20–0.50) with the total

number of seconds to complete all sub tests of the JTHFT performed with the NAH.
3. Peak force measurement of the crate task of the TAAC is expected to have a low positive correlation (0.00–0.30) with the amount of use of both hands during the task building with large construction of the OSAS.
4. Peak force measurement of the crate task of the TAAC is expected to have a low positive correlation (0.00–0.30) with the logit scores of the ABILHAND-kids.
5. Peak force measurement of the crate task of the TAAC is expected to have a low positive correlation (0.00–0.30) with the total performance score of bimanual goals related to upper extremity identified with the COPM.
6. Peak force measurement of the crate task of the TAAC is expected to have a low positive correlation (0.00–0.30) with the total satisfaction score of bimanual goals related to upper extremity identified with the COPM.

Role of the Funding Source

The funder played no role in the design, conduct, or reporting of this study.

Table 1.
Participant Characteristics[a]

Characteristics	Total
No. of children	105
Mean age ± SD	12 y 10 mo ± 3 y 6 mo
Sex	
Male	66
Female	39
Affected hand	
Left	56
Right	49
MACS[b]	
I	27
II	47
III	25
GMFCS[b]	
I	94
II	5
Zancolli[b]	
I	43
II	46
IIb	10

[a] GMFCS = Gross Motor Function Classification System; MACS = Manual Ability Classification System.
[b] Missing values.

Results

In total, 105 children and youth with UCP were included in this study. The mean age was 12 years 10 months (SD = 3 years 6 months). Of these children, 45% had Manual Ability Classification System-II, 90% Gross Motor Function Classification System-I, and 44% Zancolli-II. The participant characteristics are displayed in Table 1.

Scores of all measures were distributed over the whole range of the scales. A floor effect was seen in the data of the pitcher task with the AH, since 64% of the children could not perform the task. Descriptive values for all measures can be found in Table 2. Table 3 shows Pearson's correlations coefficients (r) between tasks of the index measure and the comparative measures. Moderate positive correlations ranging from 0.493 to 0.687 were found between tasks of the peak force measurement of the TAAC and maximal peak grip strength of the E-Link (hypothesis 1–4). Low to moderate positive correlations were found between the peak force measurement of the pitcher task of the TAAC and JTHFT performed with the AH ($r = 0.387$, hypothesis 5) and performed with the NAH ($r = 0.271$, hypothesis 6). Low positive correlations were found between the peak force measurement of the crate task of the TAAC and OSAS and ABILHAND-kids ($r = 0.259$ and $r = 0.086$, hypothesis 7 and 8, respectively). Low negative correlations were found between the peak force measurement of the crate task of the TAAC and the COPM performance and satisfaction score ($r = -0.260$ and $r = -0.271$, hypothesis 9 and 10, respectively). Based on these correlations, 8 out of the 10 hypotheses could be supported.

Discussion

The aim of this study was to investigate aspects of construct validity of the peak force during the crate and pitcher task of the TAAC instrument compared with the hypothesized partially related measures based on their construct within body function and structures and activity level. Low correlations (<0.30) indicate that constructs of the compared measures are unrelated, meaning that constructs are different, whereas high correlations (≥0.50) indicate that constructs of the compared measures are similar. If constructs are similar, compared measures are replaceable. Correlations between 0.30 and 0.50 indicate that instruments measure related but dissimilar constructs, meaning that constructs are partly the same and as a consequence in a measurement process, each of the measures (index and comparator) has their own contribution measuring partly different aspects of a broader construct.[17] Ten a priori hypotheses were formulated, and based on the results, 80% of these hypotheses could be supported, indicating that the peak

Table 2.
Descriptive Values of All Measures[a]

Measure	n	Mean	SD	Min. Score	Max. Score	Median
TAAC						
Crate (kg)	97	8.222	6.561	1.180	27.300	5.677
Pitcher AH (kg)	38	2.211	1.144	0.690	6.010	1.929
Pitcher NAH (kg)	94	3.409	1.841	0.870	8.770	3.187
E-Link						
Grip strength AH (kg)	98	8.191	6.435	1.000	30.700	6.750
Grip strength NAH (kg)	105	21.802	10.467	2.900	59.400	22.050
JTHFT AH (s)	75	220.372	158.833	34.840	651.53	185.660
JTHFT NAH (s)	75	43.142	13.709	26.160	108.030	39.730
OSAS (%)	38	88.307	12.135	33.220	100.000	91.746
ABILHAND-kids	74	4.385	1.611	1.380	6.680	3.900
COPM performance	62	6.835	1.361	2.000	9.400	7.250
COPM satisfaction	60	7.023	1.350	3.300	10.000	7.300

[a] AH = affected hand; COPM = Canadian Occupational Performance Measure; JTHFT = Jebsen-Taylor Hand Function Test; NAH = non-affected hand; OSAS = Observational Skills Assessment Score; TAAC = Task-oriented Arm-hAnd Capacity.

Table 3.
Pearson's Correlation Coefficient (r)[a]

Measure	TAAC		
	Crate	Pitcher AH	Pitcher NAH
Grip strength AH	0.493	0.687	
Grip strength NAH	0.528		0.614
JTHFT AH		0.387	
JTHFT NAH			0.271
OSAS	0.259		
ABILHAND-kids	0.086		
COPM performance	−0.260		
COPM satisfaction	−0.271		

[a] AH = affected hand; COPM = Canadian Occupational Performance Measure; JTHFT = Jebsen-Taylor Hand Function Test; NAH = non-affected hand; OSAS = Observational Skills Assessment Score; TAAC = Task-oriented Arm-hAnd Capacity.

force measurement of the TAAC concerning the crate and pitcher task can be considered to have good validity compared with the other measures. This means that the TAAC measure is a valuable addition in the measurement process because it adds new and meaningful information.

All 4 hypotheses formulated on the body function and structures level could be supported. The correlations of maximal peak grip strength measured with the E-Link were all moderately positive, ranging from 0.387 to 0.687 (hypothesis 1–4). These correlations indicate that constructs of the instruments are related, since both instruments measure strength, but are not similar.

Six hypotheses were formulated at activity level. Four of these could be supported. Correlations of JTHFT were as expected low to moderately positive, ranging from 0.271 to 0.387 (hypothesis 5 and 6), which indicates that constructs are partially related. Low positive correlations were found for the OSAS and ABILHAND-kids ($r = 0.259$ and $r = 0.086$, hypothesis 7 and 8, respectively), indicating that constructs of the measures are not related, and the TAAC adds a new construct to activity level. For the 2 measures that did not support our hypotheses 9 and 10 (COPM performance and satisfaction), low negative instead of positive correlations were found. This could be due to the fact that the COPM is not a direct performance measure as the TAAC is, and data collection took place by interviewing the parents (their opinion). Furthermore, most goals expressed as activities involving 1 or both upper extremities and formulated and scored by the parents during the COPM interview, for example, cutting with knife and fork, were not comparable with the crate task as performed with the TAAC by the child themselves. This may have contributed to the low negative correlation. This low negative correlation also indicates that the constructs of the TAAC and the COPM are different.

A limitation of this study is that it was secondary to original studies in which data were gathered. Not every comparator was performed in each study and not all data were available for each comparator, which was especially the case with the OSAS. Also, comparators were already chosen and could not be specifically selected for the purpose of this study, which would be meaningful for future research. For example, the Assisting Hand Assessment (AHA) would be a better comparator at the activity level compared with the OSAS because of its sufficient clinimetric properties.[18,19] Unfortunately, the AHA was only performed in 1 study with a lot of missing data, resulting in a very small sample size. To avoid more incomplete data sets, the AHA was not chosen as comparator. Furthermore, a high percentage (64%) of the children could not perform the pitcher task with the AH, because the pitcher could not be kept horizontal. This resulted in a small sample size compared with the pitcher task with the NAH and the crate task. For some children, the pitcher was perhaps too heavy to lift (0.533 kg); therefore, a pitcher of a lighter material can be made to allow more children to lift the pitcher. Another possibility of not being able to perform the task might be due to the position of the elbow and wrist, which is standardized in the protocol. Some children could not perform the task in this manner. When more positions of the elbow and wrist are allowed, more children might be able to perform the task. Therefore, changes in the protocol are proposed to allow more movement of the elbow and wrist.

A strength of this study is that the population included represents the population of children with UCP normally being treated in pediatric rehabilitation facilities, resulting in a heterogeneous population. Furthermore, measurements of the TAAC were all conducted by the same assessors within different studies and the population practiced within the context of ADL in all studies.

This study was a first step in the validation process of the TAAC. These results indicate that more research is needed. For future research, a larger study especially designed to investigate the clinimetric properties is desirable. A heterogeneous population representative for the population combined with more comparators, such as the AHA, needs to be included. For future research, it might also be relevant to study more ways to express additional aspects of the TAAC, for example, duration of the performance of a lifting task that could make sense in understanding functional muscle strength. At the moment, we were only interested in the capacity aspect of the TAAC to see if the TAAC is a valuable measure for measuring functional strength prior to investigating all other potential aspects of the TAAC, such as the endurance, at once. After cross-sectional and longitudinal validation, the TAAC could possibly also be used for evaluative purposes. Therefore, it is interesting to investigate the responsiveness of the TAAC and its minimal important change.

In conclusion, within the context of the ICF, the construct of the peak force measurement of the TAAC is in line with the a priori hypothesized correlations between the TAAC and different comparators on body function and structures level. The hypothesized relation of the construct of the TAAC with the comparators on activity level is only partially in line as expected and should therefore be reconsidered to some extent. The TAAC seems to be a valuable addition as it measures functional strength, which appeared to cover a construct with partial other and new elements next to the investigated comparators and therefore has its own and additional value in the assessment of these children.

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Ethics Approval

This study was approved by the Medical Ethics Review Committee of the Academic Hospital Maastricht and Maastricht University (2018–0349).

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Disclosures

The authors completed the ICMJE Form for Disclosure of Potential Conflicts of Interest and reported no conflicts of interest.

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