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ASSESSMENT PROCEDURE

Exploring relevant parameters and investigating their reproducibility of task-oriented unimanual strength measurement in children with unilateral cerebral palsy

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ABSTRACT

Purpose: To explore relevant parameters and investigate their test-retest reliability within the scope of the push button task of the Task-oriented Arm-hAnd Capacity (TAAC) measured in children with unilateral Cerebral Palsy (CP).

Methods: 118 children diagnosed with unilateral CP, aged between 6 and 18 years, participated in this study. Thetest–retest reliability of the force generated during the push button task of the TAAC was investigated using an intraclass correlation (ICC) two-way random model with absolute agreement. The ICCs were calculated across the whole age group and for two separate age subgroups (6–12 and 13–18 years).

Results: Test-retest reliability of the parameters "mean peak force of all attempts", "overshoot of force", "number of successful attempts" and "time to complete four successful attempts" were moderate to good (ICC range 0.667–0.865; 0.721–0.908; 0.733–0.817, respectively).

Conclusions: The results showed moderate to good test-retest reliability for all parameters. The parameters "mean peak force" and "number of successful attempts" are the most relevant parameters, as these parameters are task-specific and the most functional for clinical practice.

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Cerebral palsy; upper extremity; muscle strength; task-oriented; test-retest reliability

➤ IMPLICATIONS FOR REHABILITATION

- Clinical relevant information about the use of task-oriented strength during the performance of daily activity has been added to strength measurements in children with Cerebral Palsy.
- The Task-oriented Arm-hAnd Capacity instrument is a reliable, objective and simple instrument to measure task-oriented strength during daily activity and is ready for use in a clinical setting.
- The Task-oriented Arm-hAnd Capacity instrument is both a capacity and performance-based test.
- The measurement with the push button task showed moderate to good test-retest reliability.

INTRODUCTION

Arm-hand dysfunction is a common and disabling symptom of cerebral palsy (CP), particularly in children with unilateral CP [1]. These children often fail to use their affected hand (AH) spontaneously in activities of daily life (ADL). The AH is more often used when the situation demands use, such as during bimanual tasks [2]. Bimanual tasks are more complicated than unimanual tasks, because movements of both arms and hands must be temporally and spatially coordinated to complete the task [3]. Execution of bimanual tasks is often the greatest functional impairment, as most ADL require bimanual hand use. Therefore, a fundamental rehabilitation goal is to improve the child's ability to manage personally relevant ADLs.

Recent therapies mainly focus on activity level by performing goal- and task-oriented therapy. Lemmens et al. [4] investigated which goals were most commonly identified by children with unilateral CP or their parents. In 2.5–5-year-old children the most important goals were related to dressing; putting on/off pants and sweaters and open/close buttons. By the age of 6–11 years, opening/closing buttons still were the most important goal. In adolescents, the most important goals were related to eating and personal care [4]. For children with CP opening and closing buttons is a difficult task. To successfully perform this task generation of sufficient strength is essential. The Task-oriented Arm-hAnd Capacity (TAAC) recently has been developed to measure task-oriented strength during ADL, including strength while the child pushes a button [5]. Within the context of the International Classification of Functioning, Disability and Health for Children and Youth (ICF-CY), the construct of the TAAC is both at body function & structures and activity level [6]. The push button task is specifically developed to measure the strength generated to open and close a push button. It consists of static/standardized

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components; a sensor within the TAAC representing a clothing piece on which the button must be pressed, a fixed position of the push button on the TAAC and the same type of push button for each measurement. It also consists of a dynamic component, with the push button attached to a piece of leather representing part of clothes that must be pushed on the static component of the TAAC.

Execution of the push button task exists of two components: pressing and pulling the push button. Pressing the push button is often a problem, in the particular generation of force to press the button. Therefore, force while pressing the push button is our focus. The result of pressing the push button is determined by overcoming the level of resistance of the push button system. The level of resistance was set at 2.445 kg, a great resistance to overcome with the use of the fingers of the AH. To overcome the resistance of the push button system, the direction of the push force delivered, the amount of force delivered and the regulation of the push (overshoot) are essential. The direction of the delivered push force is important, as the required force to overcome the resistance becomes greater when the angle, at which the push-button is pushed, increases or decreases. Unfortunately, the direction of force delivered on the push button cannot be measured with the TAAC, but the amount of force delivered on the push button can be measured.

During the measurement of the push button task, participants are asked to push the button repeatedly for 30 s, with a maximum of 10 successful attempts. The precision of the push and the amount of force delivered on the push button contributes to a successful attempt. Several parameters are measured: "mean peak force of all attempts", "overshoot of force", "number of successful attempts" and "time to complete successful attempts in maximal 30 s". The aim of this study is to explore those relevant parameters and investigate their test-retest reliability within the scope of the push button task of the TAAC measured in children with unilateral CP. Test-retest reliability will be investigated for the whole age group, as well as separately for 6–12 and 13–18 years old subgroups since puberty may alter muscle strength and body composition [7]. It is hypothesized that the TAAC has moderate to good test-retest reliability for the push button task for all parameters, indicated by intraclass correlations ($ICC_{absoluteagreement}$) ranging between 0.60–0.80 within the whole group and separate subgroups.

Methods

Participants

Data of 118 children diagnosed with unilateral CP was used. Data were obtained in Adelante (Valkenburg, the Netherlands), Teachers College, Columbia University (New York, USA) (IRB 13-220), and a multicenter strength intervention study TOAST-CP (NL49818.015.14, METC nr 1431). After being informed, children and/or parents of all studies signed an informed consent with permission to use data for this study. This study was approved by the Medical Ethical Committee of Maastricht University Medical Centre (METC AZM/UM 2018-0349). Participants were included if they were between 6-18 years old, were diagnosed with CP and level I-III of the Gross Motor Function Classification System (GMFCS) and Manual Ability Classification System (MACS) and level I-IIb of the Zancolli classification.

Taac

The TAAC consists of a measuring unit and attachable objects, such as a crate, pitcher and push button. By attaching an object to the measuring unit the provided force of the participant can be measured during a task. More information about the measurement properties of the TAAC can be found in table 1. During the development of the push button task, resistance to push the button was determined using a universal testing machine. The button was mechanically pushed at different angles. The resistance to push the button was 2.445 kg.

During measurement with the push button participants were instructed to stand in front of the TAAC, which was mounted on a table. We choose to perform the task on a horizontal platform instead of (vertical) attached to the body because the task is already complex. The participant had to push the button repeatedly for 30 s with a maximum of 10 successful attempts. A successful attempt was to push and pull the button. Participants could use various strategies to push the button, as long as only fingers were used, and preferably the thumb to make sure that only arm-hand strength is measured. It was not allowed to use the palm of the hand since in this case forces are mainly generated by the arms. The measurement was performed with the NAH first and then with the AH.

Parameters

Several parameters were measured: "mean peak force of all attempts", "overshoot of force", "number of successful attempts", and "time to complete successful attempts in maximal 30 s".

It is important that push and pull force can be generated during a longer time period, for example when multiple buttons should be opened and closed. Therefore, the mean peak force of all attempts was used as an outcome measure. Furthermore, the number of successful attempts participants pushed the button was measured as a task-specific parameter. However, as task-oriented strength is our main focus, the peak force is the main parameter in this study.

Mechanically 2.445 kg force is required to push the button. We used the total amount of force generated and defined forces above 2.445 kg as the overshoot of force. This parameter is not task-specific, as the overshoot of force is not necessary to complete the task.

The time in which successful attempts were completed within the maximum allowed 30 s was also measured. However, this parameter is not task-specific as the completion of the task is not time-dependent. For this parameter, we first decision based on the collected data how many successful attempts the participants needed to reach to calculate the time in which successful attempts were reached.

Table 1. Measurement properties of the TAAC.

The TAAC (H.12EXTI09881; IDEE, Maastricht, The Netherlands) is an experimental prototype used for research, and will be 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, a pitcher or a push button (Figure 1). By attaching an object 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 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 the TAAC needs to be calibrated.

Table 2. Participant characteristics.

		Total	Age group 6–12 years	Age group 13–18 years
Number of children		118	79	39
Mean age ± SD		11y 2 mo ± 3 y 5 mo	9y 2 mo ± 1 y 10 mo	15y 3 mo ± 1 y 10 mo
Gender	Male	69	49	20
	Female	49	30	19
Hemiparesis	Left	60	37	23
	Right	58	42	16
MACS*	I	22	11	11
	II	52	34	18
	III	8	6	2
GMFCS*	I	74	45	29
	II	1	0	1
	III	7	6	1
Zancolli*	I	45	29	16
	II	25	19	6
	IIb	12	3	9

*Missing values of 36 participants.

Procedures

The measurement with the push button task of the TAAC was conducted twice to establish test–retest reliability. The measurements were performed during the baseline measurements of the different studies. There was at least 1-h time interval between the two measurements. For each participant, all measurements were conducted by the same assessor. In total, three assessors conducted the measurements. The assessors all had a minimum of two years of experience conducting these measurements. During the measurements all researchers used the same standardized protocol.

Data analysis

Descriptive statistics were used to characterize the study population. The output of the TAAC was converted to kilograms (kg) and peak values and time to complete a number of successful attempts were detected using Matlab. The number of successful attempts were counted manually during the measurements. Statistical analyses were performed in SPSS version 23 (SPSS Inc., Chicago, IL, USA). Test-retest reliability of all parameters of the push button were investigated, using an ICC two-way random model with absolute agreement ($ICC_{agreement}$). ICC values equal to or above 0.80 are considered to represent good reliability (8)]. Values between 0.40 and 0.79 represent moderate reliability and values less than 0.40 represent poor reliability [8]. The ICC values are presented with the 95% confidence intervals (CIs), the ICC values are our threshold for an acceptable reliability.

The limits of agreement between the measurements are displayed in Bland-Altman plots. To evaluate the measurement errors between test and retest, limits of agreement (LOA) were used. Outliers, which are extreme values that deviate from the other values in the dataset, were detected and checked if they had any influence on the outcome. If not, they were included in all analyses, otherwise they were excluded from the analyses and discussed.

Reliability was determined using the standard error of measurement of agreement ($SEM_{agreement}$) and the smallest detectable difference (SDD). $SEM_{agreement}$ was calculated to determine variability between the measurements [9]. SDD was calculated to determine the range above which a clinically important change could be measured [9].

As age could be an influence, we additionally calculated the $ICC_{agreement}$, $SEM_{agreement}$ and SDD for two age subgroups (6–12 and 13–18 years old).

Results

Data of 118 children (TOAST-CP $n = 54$; Adelante $n = 13$; Teachers College $n = 51$) diagnosed with unilateral CP were used. The participant characteristics are displayed in Table 2.

Not all 118 participants completed the task with both the NAH and AH, because of the complexity of the task. Of the 118 participants, 101 participants completed the task with the NAH and only 50 participants with the AH. Measurements that were not completed by the participants are reported as missing.

For the parameter "time to complete successful attempts within 30 s", we decided based on the collected data, how many successful attempts the participants needed to reach before calculating this parameter. Almost all participants could reach one or two successful attempts, however it is important that push and pull force can be generated for a longer time period. We chose four successful attempts, as most participants could reach this amount with both the NAH and AH, leaving us with a sufficient sample size to assess test-retest reliability.

Results of all parameters are shown in Table 3. The results are first presented for the whole group and then for the age subgroups.

Mean peak force of all attempts

The $ICC_{agreement}$ of the AH ($n = 50$) was 0.808, with a $SEM_{agreement}$ of 0.339 kg and a SDD of 0.940 kg. Two outliers were identified based on the Bland-Altman plot (Figure 2(A)). The $ICC_{agreement}$ of the NAH ($n = 101$) was 0.779, with a $SEM_{agreement}$ of 0.257 kg and a SDD of 0.712 kg. Nine outliers were identified based on the Bland-Altman plot (Figure 2(B)).

Overshoot force

The reliability and agreement variables are the same as mean peak force, only the means of both measurement are presented. Mean overshoot of force of the AH ($n = 50$) at measurement 1 was 0.532 kg, and 0.376 kg at measurement 2. Mean overshoot of force of the NAH ($n = 101$) at measurement 1 was 0.324 kg, and 0.381 kg at measurement 2.

Number of successful attempts

In Figure 3, the number of attempts of both hands are presented for all participants. The $ICC_{agreement}$ of the AH ($n = 50$) was 0.853, with a $SEM_{agreement}$ of 1.140 and a SDD of 3.160. Three outliers were identified based on the Bland-Altman plot (Figure 2(C)). The

Table 3. The results of all parameters.

	n	ICC	CI	SEM	SDD	Mean difference	LOA
Mean peak force of all attempts							
Whole group AH	50	0.808	0.664–0.891	0.339	0.940	0.156	−1.465–1.153
Whole group NAH	101	0.779	0.673–0.851	0.257	0.712	0.056	−0.949–1.062
AH 6–12	29	0.667	0.309–0.842	0.342	0.947	0.214	−1.524–1.095
AH 13–18	21	0.865	0.668–0.945	0.333	0.924	0.075	−1.400–1.250
NAH 6–12	63	0.803	0.674–0.881	0.239	0.662	0.020	−0.921–0.961
NAH 13–18	38	0.658	0.349–0.821	0.284	0.786	0.116	−0.990–1.221
Number of successful attempts							
Whole group AH	50	0.853	0.721–0.920	1.140	3.160	0.270	−4.498–3.958
Whole group NAH	101	0.857	0.788–0.903	0.949	2.630	0.860	−4.568–2.848
AH 6–12	29	0.908	0.802–0.957	0.954	2.646	0.460	−4.066–3.146
AH 13–18	21	0.756	0.400–0.901	1.351	3.745	0.060	−4.922–5.042
NAH 6–12	63	0.877	0.796–0.926	0.981	2.719	0.620	−4.393–3.153
NAH 13–18	38	0.721	0.460–0.856	0.900	2.493	1.190	−4.747–2.367
Time to reach four successful attempts							
Whole group AH	20	0.780	0.391–0.916	5.132	14.226	5.510	−23.579–12.559
Whole group NAH	86	0.787	0.673–0.861	3.840	10.643	1.608	−16.469–13.253
AH 6–12	10	0.817	0.318–0.954	3.690	10.228	2.590	−16.898–11.718
AH 13–18	10	0.733	−0.026–0.933	6.149	17.044	8.430	−28.726–11.866
NAH 6–12	49	0.790	0.628–0.881	3.889	10.779	0.873	−16.177–14.410
NAH 13–19	37	0.784	0.576–0.889	3.767	10.441	2.581	−16.813–11.651

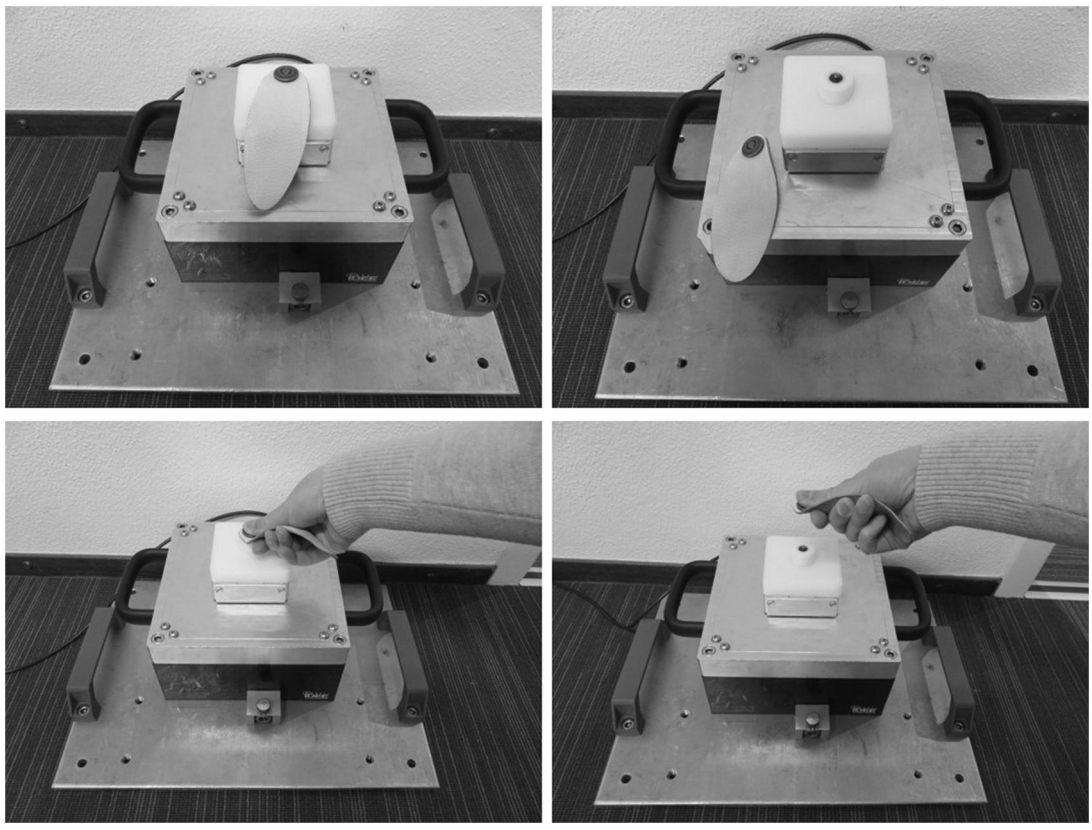

Figure 1. Push button task of the TAAC.

$ICC_{agreement}$ of the NAH ($n = 101$) was 0.857, with a $SEM_{agreement}$ of 0.949 and a SDD of 2.630. Ten outliers were identified based on the Bland-Altman plot (Figure 2(D)).

Time to complete successful attempts

The $ICC_{agreement}$ of the AH ($n = 20$ of $n = 50$) was 0.780, with a $SEM_{agreement}$ of 5.132 s and a SDD of 14.226 s. One outlier was identified based on the Bland-Altman plot (Figure 2(E)). The $ICC_{agreement}$ of the NAH ($n = 86$ of $n = 101$) was 0.787, with a $SEM_{agreement}$ of 3.840 s and a SDD of 10.643 s. Five outliers were identified based on the Bland-Altman plot (Figure 2(F)).

Age subgroups

Mean overshoot of force of the AH for the 6-12 year group ($n = 29$) at measurement 1 was 0.350 kg, and 0.135 kg at measurement 2; and for the 13-18 year group ($n = 21$) at measurement 1

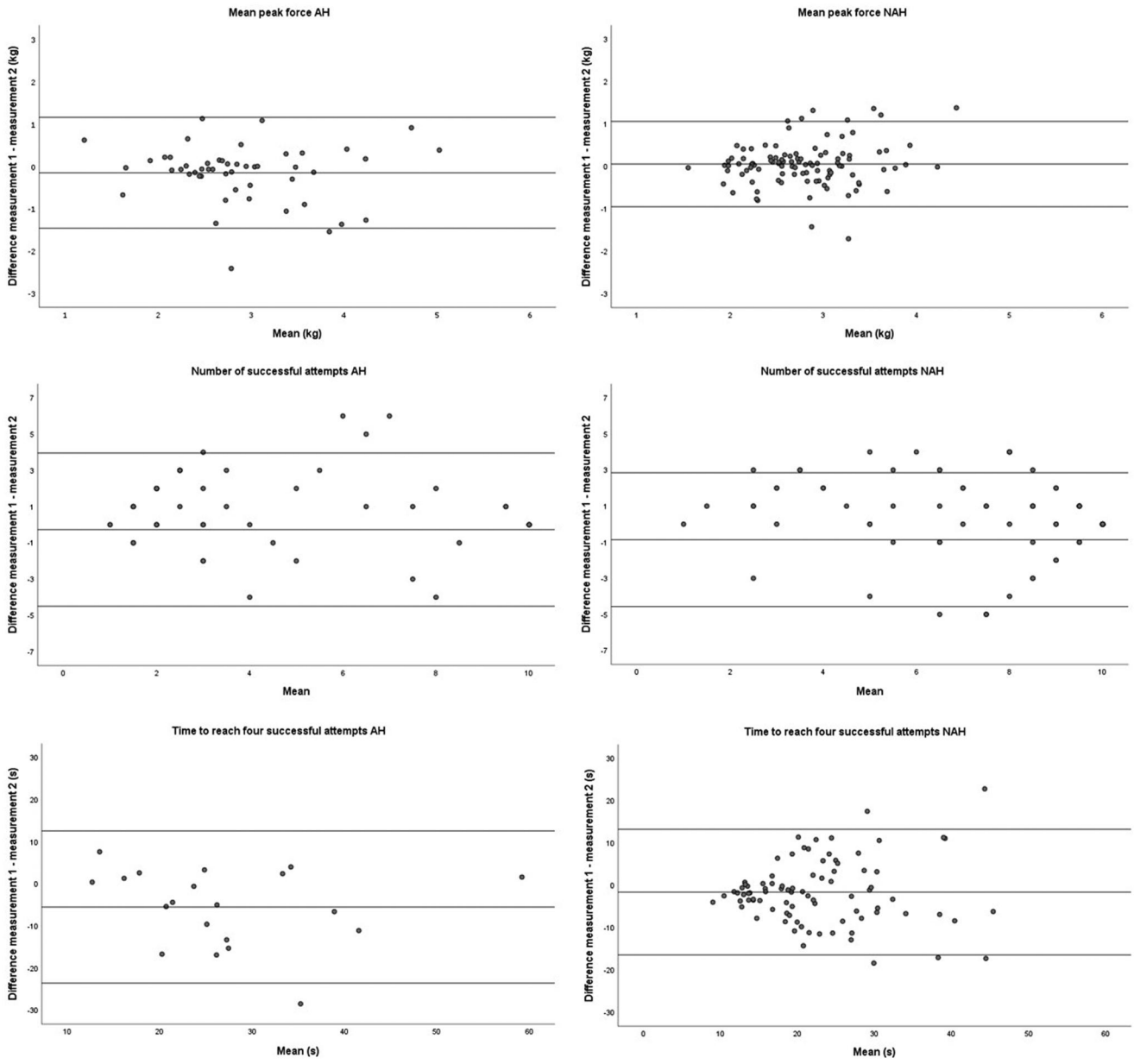

Figure 2. Bland-Altman plot for measurement 1 and measurement 2 of parameter "mean peak force of all attempts", "number of successful attempts", and "time to complete four successful attempts". The middle line shows the mean difference between the two measurements, and the upper and lower lines indicate the limits of agreement. On the X-axes, the mean of both measurements of all subjects are displayed. On the Y-axes, the differences between both measurements of all subjects are displayed.

0.783 kg and 0.709 kg at measurement 2. The mean overshoot of the force of the NAH for the 6-12 year group ($n = 63$) at measurement 1 was 0.205 kg, and 0.225 kg at measurement 2; and for the 13-18 year group ($n = 38$) at measurement 1 0.523 kg and 0.639 kg at measurement 2.

Discussion

We explored relevant parameters and investigated their test-retest reliability of the push button task of the TAAC. The parameters "mean peak force of all attempts", "overshoot of force", "number of successful attempts" and "time to complete four successful attempts within 30 s" were investigated.

Test-retest reliability of the mean peak force of all attempts was found to be moderate to good for the whole group as well as for the age subgroups (ICC range 0.667–0.865). The SDD values for mean peak force were also very promising. The SDD for the AH was 0.940 kg (32.4%) and for the NAH 0.712 kg (25.4%). After a period of therapy, these amount of improvements are required to consider changes meaningful and can be expected. Stearns et al. showed that handgrip strength improved with 2.56 kg after a two-week functionally-based Constraint-Induced Movement Therapy [10].

The mean peak force is a task-specific parameter, as force is needed to complete the task successfully. To complete the task participants had to overcome the resistance of the push button system of 2.445 kg. On average, a mean peak force of 2.899 kg was provided with the AH and 2.798 kg with the NAH. Participants were able to provide enough task-specific force to perform the task with the NAH and AH. Another force-related, but

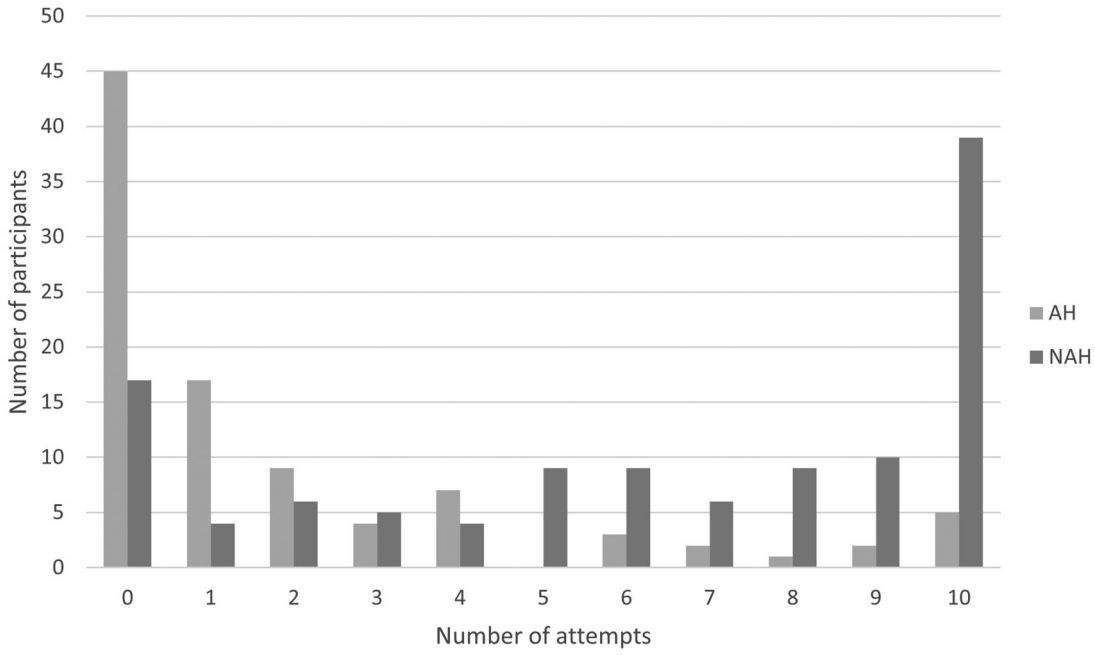

Figure 3. The number of attempts of both hands for all participants.

not task-specific, parameter is the overshoot of force. This amount of force was generated by the participant but not necessary to complete the task successfully. When looking at the results, there was a mean overshoot of force of 0.454 with the AH and 0.353 kg with the NAH. The overshoot of force was less with the NAH, because the force regulation and selectivity is better in this hand [11].

Test-retest reliability of the number of successful attempts was high for both AH and NAH (ICC = 0.853 and ICC = 0.857, respectively). Within the age subgroups, also a moderate to good test-retest reliability was found (ICC range 0.721–0.908). The number of successful attempts is a task-specific parameter and the most functional parameter for clinical practice to determine the achievement of the goal opening/closing buttons. By determining the number of successful attempts before during and after therapy, progress can be evaluated. Although results showed a good test-retest reliability, the SDD seems high. Participants, on average reached four to five attempts with the AH and seven to eight attempts with the NAH. To have a meaningful improvement participants would have to improve with more than three attempts with the AH and more than two attempts with the NAH, according to the SDD. This seems a large improvement for the AH, however the influence of therapy on the number of successful attempts has not yet been investigated.

The results of time to complete four successful attempts showed a moderate to good test-retest reliability (ICC range 0.733–0.817). However, the SDD values seem high; 14.226 s for the AH and 10.643 s for the NAH, since the maximum duration of the task is only 30 s. However, influence of therapy on the time to complete has not yet investigated.

The data also were analysed within age subgroups, as age was thought to be a potential confounder. However, when looking at the ICC values of all parameters for the whole group compared to the age subgroups, no difference can be found. This means that age does not influence the test-retest reliability of the performance of this task in this population.

There are several limitations of the instrument. Unfortunately, the TAAC is not yet able to measure direction of force. This information is assumed to be useful, since more force is needed when the angle in which the child pushes the button becomes larger. The push button task also is executed on the instrument itself, which is mounted horizontal on a table, and in a fixed position. Clothes on the other hand are flexible and worn on the body. In daily life, two hands are needed to open and close a push button, but with the TAAC only one hand performs the task. However, at present we are primarily interested in the performance of each hand individually. There are also several study limitations. One limitation is that this study was secondary to original studies in which data were gathered. Furthermore, a heterogeneous population was used, which might have resulted in higher ICC values compared to a more homogeneous population. However, the population included in this study represents the population of children with unilateral CP normally being treated in pediatric rehabilitation facilities. A strength of this study is that measurements of the TAAC were all conducted by the same assessors across the different studies.

In conclusion, results showed moderate to good test-retest reliability for the parameters “mean peak force of all attempts”, “overshoot of force”, “number of successful attempts” and “time to complete four successful attempts within 30 s”. The parameters “mean peak force” and “number of successful attempts” are the most relevant parameters, as these parameters are task-specific and most functional for clinical practice. In future research, validity and responsiveness of these parameters should be investigated. All results combined will give a good impression whether the TAAC is suitable for diagnostic and/or evaluative purposes in clinical practice. Also, it would be useful if a study could be designed to investigate clinimetric properties according to the COSMIN study design checklist [12].

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