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Validity and reliability of the Functional Dexterity Test in children

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ABSTRACT

Study Design: Clinical measurement study.
Introduction: The Functional Dexterity Test (FDT) has not been validated in children.
Purpose of the Study: To determine reliability and validity of the FDT in a pediatric population.
Methods: Intraclass Correlation Coefficients (ICCs) were used to calculate interrater and test-retest reliability in typically developing children. Pearson correlation coefficients were used to compare FDT speed with the Jebsen-Taylor Hand Function Test (JHFT) and with 2 activities of daily living tasks to establish validity in children with congenital hand differences.
Results: The FDT demonstrated excellent interrater (ICC, 0.99) and test-retest (ICC, 0.90) reliability. Pearson correlation coefficients exceeded 0.67 for JHFT subsets of fine dexterity and were all less than 0.66 for JHFT subsets of gross grasp. Correlations with the activities of daily living tasks were good to excellent. FDT speeds in TD children exceeded those of children with congenital hand differences ($P < .001$), demonstrating discriminant validity.
Discussion: Children with congenital hand differences are often treated early in life, making it important to reliably assess hand function of these young children to distinguish developmental change from changes due to interventions. The FDT can reliably measure functional progress over time, help clinicians monitor the efficacy of treatment, and provide families realistic feedback on their child's progress.
Conclusion: The FDT is a valid and reliable instrument for the measurement of fine motor dexterity in children.

Introduction

Dexterity is an integral part of a complete evaluation of function in the hand. An examination of dexterity provides information about the ability of an individual to use a combination of sensation and intrinsic and extrinsic hand muscle function to produce manipulative skills and dexterous movements. These skills are important in adults, but even more so in children where development of dexterity plays a large role in their functional and physical development. Evaluation of hand function poses specific challenges in the pediatric population. In addition to the inherent difficulties of holding the attention of a child, an appropriate test needs to be accomplished quickly and simply so that children with a wide range of cognitive and physical abilities can complete it while providing the tester sufficient information to determine the child's ability.

To be widely used, an outcome instrument should have information available regarding its clinimetric properties, such as reliability, validity, and normative values.[1-3] Reliability is the consistency of a test; that is, the ability of a test to measure similar results under consistent conditions. This is commonly defined by determining interrater reliability and test-retest reliability. Validity is the accuracy of a test; the extent to which a test measures what it is intended to measure. There are various types of validity. Construct validity can be established through convergent and divergent analyses, which ascertain whether the test in question actually measures what it was intended to measure. This type of validity is frequently established by comparison to a gold standard. Discriminant validity determines how well a test can discriminate between different groups. Ideally, in addition to having strong clinimetric properties, an outcome instrument should also be portable, low cost, easy to administer, and time efficient.

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Fig. 1. Functional Dexterity Test (FDT). The pegs are turned over and replaced in the pegboard using tripod pinch and manipulating the peg within the hand.

The Functional Dexterity Test (FDT, Fig. 1) was designed to measure the performance of in-hand manipulation and tripod pinch, a pattern of hand use that typically develops by 3 years of age.[4] Under the framework of the International Classification of Functioning, Disability and Health, the FDT falls under the Body Function (b760—control of voluntary movement functions) and Activity and Participation (d440—fine hand use) domains, with a focus on capacity.[5,6] Capacity refers to a person's willingness and ability to perform a given task. The FDT has been shown to be a reliable and valid tool to test the capacity of dexterity in adults, with scores that correlate well with the ability to perform activities of daily living.[7,8] Adult normative values have been published.[7,8] The test has been both evaluated and used as a functional outcome measure for a variety of conditions.[5,9-17] Although pediatric norms are available,[18] other clinimetric properties have not yet been established for the FDT in a pediatric population. Therefore, the purpose of this study was to determine the reliability and validity of the FDT in children.

Methods

Study participants

With institutional review board approval and written informed consent from parents, data from 2 different cohorts of children were prospectively collected. Figure 2 shows the study schema. For interrater and test-retest reliability, typically developing (TD) children were recruited from local summer day camps. Exclusion criteria were the presence of neurologic or musculoskeletal disorders, prior upper limb trauma, or the inability to understand the instructions to complete the test. Participating parents filled out a medical questionnaire to screen for eligibility. The sample of TD children was part of a larger, previously reported study establishing pediatric normative values for the FDT.[18] For validation, a convenience sample of children with congenital hand differences was recruited from a pediatric hand surgery specialty clinic. Children were excluded if they had undergone surgical intervention within the year before testing or were unable to understand the instructions to complete the tasks.

FDT administration and scoring

The FDT (North Coast Medical, Gilroy, CA) consists of 16 cylindrical pegs arranged on a peg board in 4 rows of 4 pegs. A tripod pinch is normally used to turn over each peg and replace it in the pegboard in a standardized pattern. The test was administered as previously described.[18] A height adjusted table was used and hand dominance was determined by asking the child to draw a circle with a pen placed in the center of the table. The hand the child spontaneously used was documented as the dominant hand. After testing instructions were given, a practice trial was performed to minimize learning effect. The second trial was timed by a stopwatch and recorded in seconds. If a peg was dropped, time was stopped and the peg was returned to its original position. Time was restarted once the child resumed turning pegs. Unlike the adult testing protocol, no penalties were assessed. In children, inefficient movements are reflected in decreased speed. The FDT is

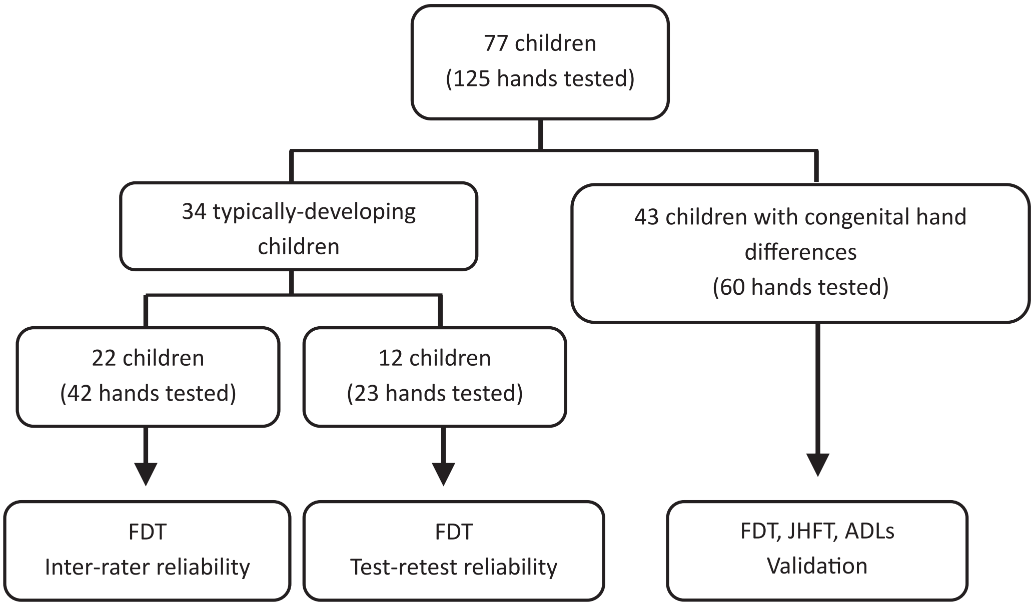

Fig. 2. Study flow chart. FDT = Functional Dexterity Test; JHFT = Jebsen-Taylor Hand Function Test; ADL = activities of daily living.

sensitive enough to detect functional inefficiencies of in-hand manipulation, and thus, penalties have been eliminated from pediatric FDT scoring.[18] In addition to measuring the time to task completion, performance on the FDT is expressed as the rate of task completion, that is, speed (number of pegs turned per second).[18,19]

Interrater reliability

One subset of TD children was administered the FDT by 3 testers in a single setting. The participants were randomized as to which hand was tested first, the dominant or nondominant hand. The testers alternated giving the verbal instructions and practice trial. The testers simultaneously timed the test performance of each child, blinded to each other's results.

Test-retest reliability

A second subtest of TD children was administered the FDT on 2 different days by the same tester. The participants were randomized as to whether the dominant or nondominant hand was tested first, and the order of testing was maintained from the first day to the second day.

Construct validity

Jebsen-Taylor Hand Function Test (JHFT)

Children with congenital hand differences participated in the validation portion of this study. Each child's testing was completed in one session, and both hands were tested. The JHFT was selected as the gold standard for comparison because it is well established and includes a variety of simulated functional tasks that require both fine and gross hand dexterity. The JHFT, originally described in 1969, was created to provide quantitative measurements of standardized tasks to assess broad aspects of hand function commonly used in everyday activities.[20] A validated outcome instrument, the JHFT has been reported in hundreds of studies.[21]

The JHFT consists of turning over five 3 × 5–inch index cards, picking up 6 small common objects, feeding simulation using a spoon and 5 kidney beans, stacking 4 checkers, picking up large light objects (empty aluminum cans), picking up large heavy objects (one pound aluminum cans), and copying a 24-letter sentence. As is often the case when testing pediatric populations, we excluded the writing portion because some of the participating children were of an age where writing is not yet an acquired skill.[22-24] The time to completion for each of the remaining 6 subsets was measured by stopwatch and recorded in seconds.

To compare scores on the JHFT to the FDT scores, time to completion of each subset of the JHFT was converted to speed. For example, the number of large heavy cans moved (5) was divided by the elapsed time to get the speed of the subtest, expressed as cans/second.

Activities of daily living tasks

Two representative activities of daily living that require tripod prehension were tested—buttoning a large button and lacing a shoelace through a series of grommets. These 2 activities were part of a commercially available dressing board suitable for toddlers. We based the selection of these activities on a study by Aaron and Stegink-Jansen, which showed a strong correlation between FDT scores and activities of daily living (ADL) in adults.[7] The time to completion of each task was timed by a stopwatch and recorded in seconds, then converted to speed for analysis.

Table 1
Demographic data of participants

Demographics	Typically developing children		Children with congenial hand differences
	Interrater ($N = 22$)	Test-retest ($N = 12$)	Validation ($N = 43$)
Age in years (SD)	7.9 (1.7)	11.0 (2.7)	10.0 (3.8)
Range	6.0-11.9	7.3-15.8	3.0-17.0
Sex			
Female	5	4	19
Male	17	8	24
Hand dominance			
Left	2	1	24
Right	20	11	19
Affected hand			
Left	N/A	N/A	8
Right			17
Bilateral			18

N/A = not applicable.

Discriminant validity

Discriminant validity was assessed by comparing the FDT speeds of the children with congenital hand differences with the FDT speeds of the TD cohort.

Statistical analysis

Means and standard deviations (SDs) of FDT speeds for each cohort were calculated. Intraclass correlation coefficients (ICCs [2, 1]) were calculated using a mixed model to obtain interrater and test-retest correlations. The smallest detectable difference (SDD) is the amount of change between tests needed to detect a real difference in performance.[25,26] For a 95% confidence level, the SDD is calculated as: $SDD = 1.96 \times \sqrt{2} \times SEM$. The standard error of measurement (SEM) is calculated using the formula: $SEM = SD\sqrt{(1-ICC)}$.

Two-tailed Student t test was used to compare the TD cohort FDT speeds to those of the children with congenital differences. Significance was set at $P < .01$. Pearson correlation was calculated to compare FDT speed with the speed of each subset of the JHFT and with the 2 timed ADL tasks. Correlations were calculated for the entire cohort and by hand dominance. Correlations were categorized as excellent (>0.8), good (0.6-0.8), fair (0.4-0.6), or poor (<0.4).[27] Scatter plots of correlated variables were examined to confirm linearity of relationships and the absence of outliers.[28]

Results

Interrater reliability

Twenty-two TD children (42 hands) were administered the FDT while being timed by 3 examiners simultaneously. Two children

Table 2
Mean speed (pegs/second) and standard deviation (SD) of FDT speed in test-retest reliability group of typically developing children by hand dominance

Typically developing cohort	FDT test	FDT retest
	Mean speed (SD)	Mean speed (SD)
Total hands	0.75 (0.16)	0.81 (0.17)
N	23	23
Dominant hands	0.79 (0.17)	0.82 (0.17)
N	12	12
Nondominant hands	0.72 (0.14)	0.79 (0.17)
N	11	11

FDT = Functional Dexterity Test; SD = standard deviation.

Table 3
Summary of diagnoses for children in the validation cohort

Diagnosis	Number of hands	Number of children
Duplicate thumb	2	2
Triphalangeal thumb	2	1
Hypoplastic/absent thumb	8	6[a]
Radial longitudinal deficiency	7	4
Ulnar longitudinal deficiency	2	2[a]
Poland sequence, symbrachydactyly	3	3
Symbrachydactyly	7	7
Syndactyly	2	2
Camptodactyly	2	1
Ectrodactyly	4	3
Digital amniotic constriction bands	5	3
Metacarpal synostosis	1	1
Radioulnar synostosis	2	1
Congenital radial head dislocation	2	1
Brachial plexus birth palsy	3	3
Amyoplasia	4	2
Escobar's syndrome	4	2

[a] Two bilaterally affected children are listed twice; one child had an ulnar longitudinal deficiency and a contralateral hypoplastic thumb, the other had a transverse deficiency at the level of the carpus and a contralateral ectrodactyly. A total of 18 children were affected bilaterally.

were only scored on 1 hand as the other was injured and in a cast at the time of testing. The mean age was 7.9 years (range, 6.0-11.9 years), with 5 girls and 17 boys. Twenty children (91%) were right-hand dominant (Table 1). The ICC (2, 1) between the 3 raters was 0.99 (95% confidence interval, 0.99-1.00; $P < .0001$).

Test-retest reliability

Twelve TD children (23 hands) were administered the FDT at 2 separate testing sessions by the same examiner. One child had an acutely injured hand at the time of testing, so was only scored on one hand. The mean age was 11.0 years (range, 7.3-15.8 years), with 4 girls and 8 boys. Eleven children (92%) were right-hand dominant (Table 1). The mean interval between testing sessions was 3.5 days (range, 1-27 days). The means and SDs of the FDT speeds (in pegs/second) for the group and by hand dominance are shown in Table 2. The ICC (2, 1) between the 2 tests was 0.90 (95% confidence interval, 0.783-0.957; $P < .0001$). The SEM, calculated using an ICC of 0.9 and SD of 0.132, was 0.04 pegs/second. The SDD was 0.116 pegs/second, meaning that 2 scores must be at least 0.116 pegs/second, or 15% different to be considered a real change.

Validity

Forty-three children (84 hands) with congenital hand differences participated in the study. The mean age was 10.0 years (range, 3.0-17.0 years), with 24 boys and 19 girls. Nineteen children (44.2%) were right-hand dominant, and 18 (42%) were bilaterally affected. Demographic data are summarized in Table 1. Their diagnoses are listed in Table 3. Thirty-one children had undergone surgical reconstruction of their affected upper limb.

Table 5
Pearson correlation coefficients between the FDT and the JHFT subsets of children in the validation group.

JHFT subset	Movement pattern (ICF classification)	FDT all	FDT Dom	FDT ND
Small objects	Picking up (d4400)	0.782	0.751	0.776
Card turn	Manipulation (d4402)	0.715	0.745	0.671
Checkers	Manipulation	0.741	0.823	0.638
Simulated feeding	Picking up, release (d4403)	0.655	0.650	0.581
Large heavy can	Grasp (d4401), release	0.652	0.755	0.574
Large light can	Grasp, release	0.632	0.658	0.602

Dom = dominant hand; FDT = Functional Dexterity Test; ICF = International Classification of Functioning, Disability, and Health; ND = nondominant hand.

The mean speeds and SDs for the FDT and the JHFT subsets are shown in Table 4. The FDT speeds of the children with congenital hand differences were significantly slower than the FDT speeds TD children ($P < .001$). Correlations of the FDT with the JHFT subsets are summarized in Table 5. The highest correlations were found between the FDT and JHFT subsets that test fine motor dexterity, including card turning ($r = 0.72$), manipulation of small common objects ($r = 0.78$), and stacking checkers ($r = 0.74$). Lower correlations were found for the subsets testing grasp and release, specifically the feeding simulation ($r = 0.66$), moving large light cans ($r = 0.63$), and moving large heavy cans ($r = 0.65$).

The correlation coefficients for the 2 tripod activities of daily living are presented in Table 6. Correlation coefficients were greater than 0.71 for the lacing task for the dominant and nondominant hand. For the buttoning task, the dominant hand Pearson product-moment correlation was 0.65. There was one outlier in this group; with that outlier excluded, the correlation improved to 0.74.

Discussion

Study results

This study demonstrated excellent interrater (ICC, 0.99) and test-retest (ICC, 0.90) reliability for the FDT in TD children. The SDD was calculated as 0.116 pegs/second, meaning an FDT score must differ by at least that much to be considered a real change or difference. FDT speeds of TD children significantly exceeded those of children with congenital hand differences ($P < .001$), demonstrating discriminant validity.

Convergent validity was established by good correlations between FDT speed and the JHFT subsets that test fine dexterity, specifically manipulating small objects, stacking checkers, and turning 3×5–inch index cards. Correlations with the ADL tasks fell in the good to excellent range as well. Divergent validity was

Table 4
Mean speed (pegs/second) and standard deviation of FDT and JHFT subsets of children in the validation group

Cohort	FDT	JHFT					
	Mean speed (SD)	Card turn mean speed (SD)	Small object mean speed (SD)	Feeding mean speed (SD)	Checkers mean speed (SD)	Large light can mean speed (SD)	Large heavy can mean speed (SD)
Total hands	0.54 (0.19)	0.73 (0.33)	0.61 (0.22)	0.38 (0.19)	1.21 (0.81)	1.03 (0.42)	0.94 (0.42)
N	79	77	77	76	77	77	72
Dominant hands	0.60 (0.20)	0.82 (0.34)	0.68 (0.19)	0.44 (0.17)	1.40 (0.78)	1.13 (0.41)	1.01 (0.39)
N	42	37	37	37	37	37	35
Nondominant hands	0.47 (0.16)	0.65 (0.32)	0.54 (0.22)	0.31 (0.18)	1.02 (0.80)	0.95 (0.42)	0.88 (0.43)
N	37	40	40	39	40	40	37

FDT = Functional Dexterity Test; JHFT = Jebsen-Taylor Hand Function Test; SD = standard deviation.

Table 6
Pearson correlation coefficients between the FDT and 2 tripod activities of daily living of children in the validation group.

ADL	FDT Dom	FDT ND
Lacing	0.842	0.708
Button	0.654	0.807

Dom = dominant hand; FDT = Functional Dexterity Test; ND = nondominant hand; ADL = activity of daily living.

demonstrated by lower correlations with the JHFT subsets that test grasp and release—scooping beans with a spoon and moving large light and large heavy cans. These findings not only substantiate validity of the FDT for its use in children but also strengthen the evidence of the test as a tool to evaluate fine dexterity, specifically tripod tasks and tasks that require in-hand manipulation.

Children with congenital hand differences are often treated early in life, making it important to reliably assess hand function of these young children to distinguish developmental change from changes due to interventions. One of the challenges is that the test needs to be short and easy to administer, age appropriate, and easy for young children to understand. Based on our study results, the FDT can be used in children as young as 3 years old. Our study results support observations by Pehoski[4] that children of this young age already have already developed a pattern of in-hand and tripod pinch manipulation. In addition, these young children were able to understand the aim of the test to complete the task as fast as possible without being distracted and were thus able to show the capacity to perform the FDT in a consistent way.

The functional capabilities of children born with hand differences are frequently underestimated by parents and clinicians. Clinical experience tells us that children with congenital upper limb differences function better than adults with a similar acquired deformity. The speed to perform the FDT was less in the children with congenital hand differences than their TD counterparts, with TD children achieving a mean of 0.75 (SD 0.16) pegs/second, and children with congenital hand differences achieving a mean of 0.54 (SD 0.19) pegs/second. This difference in FDT speeds exceeds the SDD of 0.116, separating the congenital cohort from the TD cohort. Further research is needed to see if this difference is of clinical relevance for children to fulfill their life roles. The FDT demonstrated sufficient reliability to measure progress over time that is related to functional tasks, to help clinicians monitor the efficacy of treatment, and to provide families realistic feedback on their child's progress.

Study limitations and future research

This study has several limitations. All subgroups were made up of convenience samples of children. Although a diverse population is served, and therefore presumably sampled, specific data on race and ethnicity were not recorded. Regardless of cohort heterogeneity, the subjects were all recruited from the same geographic region, and thus, results may not reflect a wider population. In addition, while calculating the SDD is useful information, the minimum clinically significant difference is unknown.[29] Finally, we did not account for other factors that may potentially affect dexterity, such as sports participation, or experience playing a musical instrument.

Future studies need to address reliability of the FDT when used in children with acquired deformities, traumatic injuries, or cognitive impairment, as well as the responsiveness of the test to change and the minimum clinically significant difference. Future studies may also include correlation of the FDT with contemporary tasks of instrumented daily living such the capacity and performance of using keyboards, cellular phones, and video games, and the impact of dexterity on self-reported perceptions of participation and quality of life.

Conclusions

Clinicians are under increasing pressure to evaluate treatment in a standardized manner and provide outcomes data demonstrating efficacy and justifying reimbursement. The current health care environment emphasizes both the measureable effectiveness of treatment and time efficiency. In keeping with these requirements, dexterity should be evaluated with tests that are reliable, valid, responsive, and clinically time efficient. The FDT can be recommended to fulfill these demands as a valid and reliable instrument for the measurement for fine motor dexterity in children.

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