Hand Dexterity in Children: Administration and Normative Values of the Functional Dexterity Test

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Purpose To document normative values from the Functional Dexterity Test (FTD) for typically developing children and to optimize test administration and interpretation.

Methods A total of 175 typically developing children aged 3 to 17 years participated in the study. Children completed the 16-peg FDT with both hands, and elapsed time was recorded in seconds. Data were analyzed as 16/time, interpreted as speed (pegs per second). A linear regression analysis predicted speed from age and hand dominance.

Results Functional Dexterity Test speed increased linearly in typically developing children by 0.04 pegs/s for each year of age. This rate of increase was the same for dominant and nondominant hands. Dominant hands were faster than nondominant hands by 0.09 pegs/s at all ages. There was no sex difference.

Conclusions This study provides age-specific normative values for functional dexterity in typically developing children in 2 formats: as a growth chart of FDT speed versus age and as a regression model that calculates expected speed given a child's age and tested hand dominance. Recommended pediatric modifications to the FDT are to use speed (pegs per second) instead of time (seconds) to report results, and to not assess penalties. The norms presented allow clinicians to compare both speed and rate of change over time of pediatric patients with typically developing children, which makes it possible to distinguish developmental change from intervention. *(J Hand Surg Am. 2013;38(12):2426−2431. Copyright © 2013 by the American Society for Surgery of the Hand. All rights reserved.)*

Type of study/level of evidence Diagnostic III.

Key words Dexterity, Functional Dexterity Test, pediatric normative data.

DEXTERITY, AS A MEASURE of hand function, is an important component of a thorough hand evaluation. This is especially true in children, for whom the relationship between the commonly measured parameters of range of motion, sensation, and strength may not reflect actual functional ability.[1] However, clinicians do not routinely administer standardized dexterity tests because of time constraints, the complexity of the tests, and the inherent difficulties in evaluating young children.

There are few pediatric norms for existing, validated dexterity tests. Although the Jebsen−Taylor Test of Hand Function[2] is well-established, it is lengthy and difficult to administer in young children.[3]

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FIGURE 1: The Functional Dexterity Test. The pegboard consists of 16 cylindrical pegs, each 4 × 2.2 cm, arranged in 4 rows of 4 pegs on a pegboard that is 20.6 × 20.6 × 3.7 cm.

In addition, it is valid only for patients over 6 years of age.[4] Children with congenital hand differences are often treated early in life, which makes it important to have a tool that can reliably assess young children. The 9-Hole Peg Test has normative data for 5- to 10-year-olds[5] and 4- to 19-year-olds[6]; the Purdue Pegboard has norms for 2.5- to 6-year-olds,[7] 5- to 15-year-olds,[8] and 14- to 19-year-olds.[9] Norms for children 3 to 20 years of age were obtained as part of a study comparing the 9-Hole Peg Test with a modified Kiddie Grooved Pegboard Test.[10]

The Functional Dexterity Test[11] (FDT) is a timed pegboard test consisting of 16 thick cylindrical pegs arranged in 4 rows of 4 pegs each (Fig. 1). Patients turn over all of the pegs in a specified order by manipulating each peg in their hand. Unlike other pegboard tests that evaluate only grasp and release, the FDT measures tripod pinch and in-hand manipulation. When validated in adults, it was shown to be well-associated with the ability to perform activities of daily living, such as fastening a button or tying a knot.[11] In a comparison of clinometric properties of performance tests in adults (including the FDT, Jebsen−Taylor Test, Purdue Pegboard Test, Box and Blocks Test, 9-Hole Peg Test, Grooved Pegboard Test, Sollerman Hand Function Test, and Moberg Pick Up Test), the FDT received the best ratings.[12] The advantage of the FDT is that it provides clinically relevant functional data with an easily and rapidly performed test.

We sought to investigate the utility of the FDT in the pediatric population. The specific purposes of this study were to document age-specific normative values for functional dexterity in typically developing children ages 3 to 17 years and to optimize test administration and interpretation of results.

MATERIALS AND METHODS

Study participants

With institutional review board approval and written informed consent from parents, we recruited typically developing children in local summer day camps to participate in the study. Participating parents filled out a brief medical questionnaire to screen for existing neurological or musculoskeletal disorders or prior upper extremity trauma. A total of 175 typically developing children aged 3 to 17 years (mean, 9.4 y) participated in the study. There were 87 boys and 88 girls; 156 participants were right-handed. By parent report, 93 participants were white, 42 were African-American, 22 were Asian, 12 were Hispanic, and 6 were of mixed race.

Testing procedure

Participants were seated comfortably at a height-adjusted table. Hand dominance was established by asking the child to draw a circle with a pen placed in the center of the table. The hand the child naturally used without prompting was recorded as the dominant hand. The FDT is commercially available (North Coast Medical, Gilroy, CA) or can be fabricated using the detailed dimensions and schematic provided by Aaron and Jansen.[11] The FDT board was placed 10 cm from the edge of the table closest to the child. Participants were instructed to pick up each peg, turn it over in their hand while refraining from supinating or touching the table with the peg, and reinsert it into the pegboard as quickly as possible, beginning with the top row and proceeding in a zigzag fashion through all 4 rows. For example, if the right hand was being tested, the subject would begin at the left-most peg in the row farthest from him, complete that row from left to right, move to the peg directly below, and complete the second row from right to left, continuing in this pattern until the end (Fig. 2). For ease of use, the pegs were painted different colors on each end. The child was instructed to "Make all the pegs change color with only 1 hand. Don't touch the pegs to the board or your body, try not to turn your hand palm-up, and don't help with your other hand. Do it as quickly as you can without dropping a peg. Do it in this pattern." At that point, the tester pointed to the starting peg and proceeded to turn over 2 rows in the proper sequence to demonstrate. The pegs were turned back to the starting color, and the test commenced.

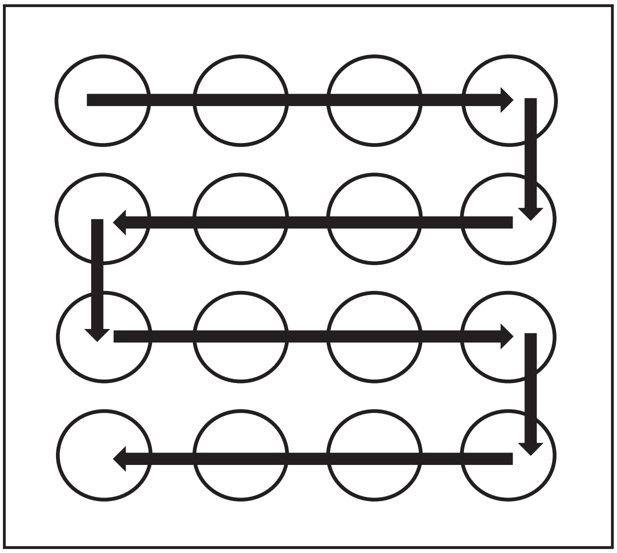

FIGURE 2: Example of peg-turning sequence for testing a right hand. Patient begins with the top left peg and proceeds in a zigzag fashion through all 4 rows, ending at the bottom left peg.

One complete practice trial was performed to minimize learning effect; then the second trial was timed. Elapsed time in seconds was measured with a stopwatch and recorded. If a peg was dropped, time was stopped and the peg was returned to its original position. The child was asked to continue, and time keeping resumed when the child's fingers contacted the peg. All participants had both hands tested and were randomized as to whether the dominant or nondominant hand was tested first. In the only deviation from the original testing protocol, [11] no penalties were assessed.

Statistical analysis

We analyzed data as 16/time (seconds), interpreted as speed (pegs per second). A linear regression analysis predicted speed from age (y), and hand dominance (1 = dominant; 0 = nondominant). Age was recorded in days and converted to fractional years. Secondary analyses were performed to evaluate for any effect of sex.

RESULTS

The FDT speed (pegs per second) increased linearly with age for both dominant and nondominant hands (Fig. 3). Dexterity continued to improve throughout adolescence, and dexterity gains did not plateau or change rate through age 17 years. Dominant hands were faster than nondominant hands at all ages, and the difference between dominant and nondominant hands remained constant at 0.088 pegs/sec at all ages. There was no sex difference ($P = .34$). The results can be modeled by the following regression model:

$$\text{Dexterity} = 0.215 + 0.037(\text{Age[y]}) + 0.088\ \text{Dominant hand}.$$

To predict expected speed for a child between the ages of 3 and 17 years, start at 0.215 pegs/s, add 0.037 for each year of age, and add 0.088 if the dominant hand is being tested. The R^2 shows that 66% of the variability in speeds is accounted for by this regression. Table 1 shows the regression analysis.

Discussion

We selected the FDT for 2 reasons. First, it tests dynamic in-hand manipulation using 3 jaw chuck prehension rather than the static grip or simply grasp and release patterns examined by other dexterity tests. Second, the FDT is well-suited for pediatric assessment because the pegs (4 × 2.2 cm) are a good size for even young children to manipulate. The testing apparatus is straightforward and engaging, and the test itself takes little time to administer, accommodating both a child's attention span and a busy clinic setting.

Speed versus time

Accuracy and time to completion are the parameters typically used to measure dexterity.[11] However, for analysis, test results recorded as elapsed time pose several challenges. No suitable value is available to assign to patients who fail to complete the trial. Because time values cannot be less than 0 but are unbounded from above, the distribution of times for any homogeneous population is usually skewed toward the high end. Skewed distributions do not satisfy the assumptions of common statistical methods, which complicates analyses. In addition, when time values are related to another variable (such as the age of participants in this study), they generally violate 2 basic assumptions required by linear regression analysis. First, they tend not to be linearly related—a fundamental requirement for a linear regression model. Second, they tend to be more spread-out for larger values than they are for smaller ones, which violates the regression assumption of equal variance. These attributes also make it statistically inappropriate to summarize their association with other variables with a Pearson correlation coefficient.

A simple and effective way to address this problem is to work with the reciprocal of time. Time is measured in seconds per 16-peg board, so its reciprocal is properly interpreted as speed. For the FDT, we recommend working with 16/time = speed (pegs per second). The distribution of speeds is generally nearly

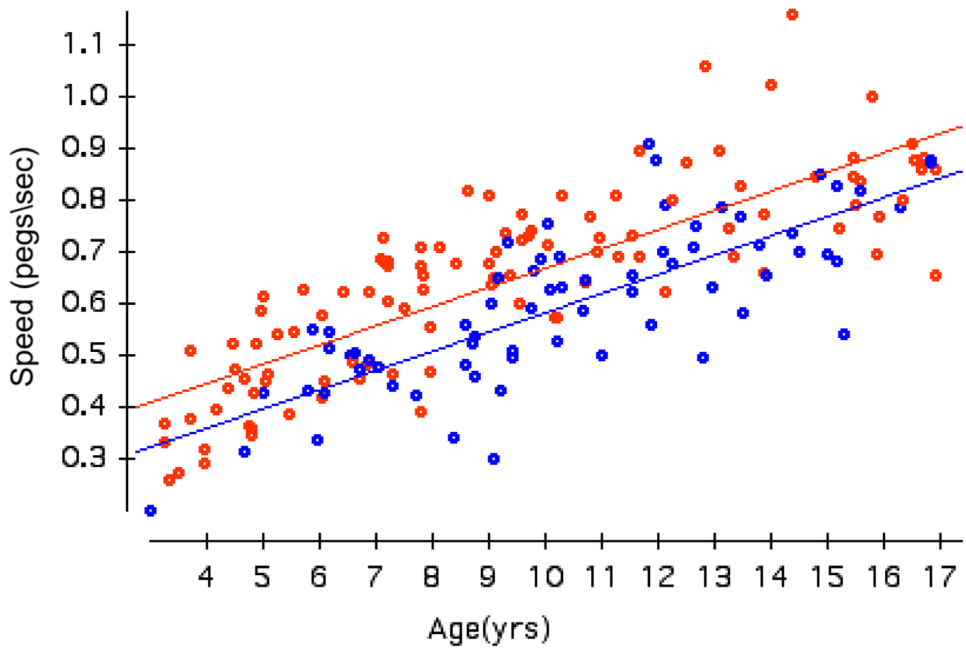

FIGURE 3: Scatterplot of FDT results showing speed (pegs per second) versus age. Dominant hands are in red and nondominant hands are in blue.

TABLE 1. Regression Analysis

Variable	Coefficient	SE (Coefficient)	*t* Ratio	*P* Value
Intercept	0.21	0.03	8.60	≤ .000
Age, y	0.04	0.00	18.00	≤ .000
Dominant?	0.09	0.01	5.50	≤ .000

R^2 squared = 66.0%; R^2 (adjusted) = 65.6%; standard deviation of the residuals = 0.10 with 175 − 3 = 172 degrees of freedom.

symmetric for homogeneous populations of patients. Patients who fail to complete the test either can be assigned a speed of 0 or have a speed calculated from the total number of pegs completed and the number of seconds elapsed. Transforming to speed simplifies the relationship of measurements with other variables.[13]

Normative values

Having population norms for a functional test is particularly helpful with pediatric populations, because ability changes with growth and development. Even if the absolute values for a population are not expected to reach normal values, comparing the rate of development over time is valuable. Lee-Valkov et al[1] obtained normative FDT values for 3-, 4-, and 5-year-old typically developing schoolchildren. Staines et al[3] reported on dexterity in 10 children 2.8 years after pollicization, and 5-year interval data on the same cohort[14] using the FDT as 1 of their functional tests. They noted that the FDT discriminated "intrinsic manipulative movements" better than the Jebsen−Taylor Test.[14]

Figure 4 presents the normative values as a growth chart of FDT speed versus age. This facilitates easy visualization of expected speed for any given age using a continuous age scale. The use of regression on fractional age provides a more precise estimate of performance than would be possible by grouping subjects into arbitrary age categories. Clinicians who treat children are accustomed to this format for tracking height and weight age-based norms, and it has been successfully used for reporting pediatric hand strength parameters.[15,16] Alternatively, clinicians may prefer to use the formula provided by the regression model to calculate the expected normal speed given a patient's age and hand dominance of the tested hand.

Scoring the Functional Dexterity Test

As originally described in adults, specific penalties were assessed during FDT administration (Table 2) and added to the raw time to give the final score.[11]

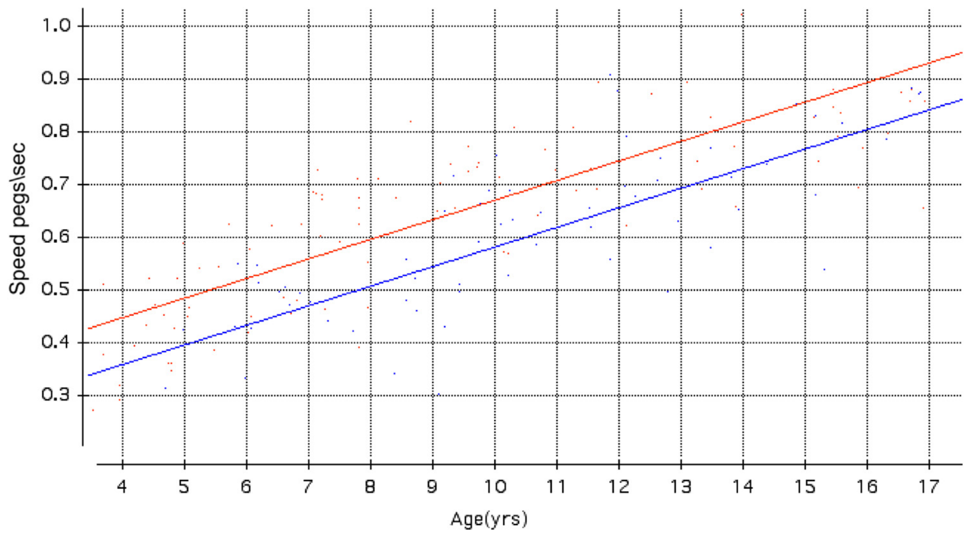

FIGURE 4: Growth chart for use in locating normal speeds for ages 4 to 17 years. The red line indicates the dominant hand, and the blue line the nondominant hand.

TABLE 2. Adult and Pediatric Penalties

Penalty Added	Original Adult Penalty[1]	Pediatric Modification[3]
10 s	Drop peg	
5 s	Touch board	Touch peg against chest
	Supinate forearm while turning peg	Drop peg
		Switch hands during test
		Assist from nontesting hand

The intent of penalties was to include a measure of quality of movement; however, assessing penalties poses several problems. In adults, it decreases the inter-rater and intra-rater reliability of the FDT. In 30 normal adults, the inter-rater reliability went from greater than 0.99 for raw time alone to 0.73 to 0.88 when including penalties; the intra-rater reliability similarly changed from greater than 0.90 to greater than 0.72.[11]

A second problem is that adult penalties are not applicable to children. When Lee-Valkov et al[1] obtained normative values for 3- to 5-year-old schoolchildren, they found the adult penalties to be inappropriate and modified them to better accommodate the pediatric population (Table 2). Grasp and movement patterns develop over time,[17] so to truly assess pediatric penalties would require a menu of changing age-specific items, which would hamper the ease of test administration. This study shows that inefficient movements are reflected in a decreased speed and do not require additional adjustment with penalties. The FDT is sensitive enough to detect functional inefficiencies in in-hand manipulation. Therefore, we recommend omitting penalties altogether.

The FDT can provide an objective assessment of in-hand manipulation in a manner that is easy to conduct and suitable for young children. This is helpful to develop preintervention planning, to quantify postintervention changes, and to track physiologic development. Further studies are under way correlating the FDT with functional activities in children with injuries or congenital differences.

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