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Scientific/Clinical Article

Establishing normative data for the Functional Dexterity Test in typically developing children aged 3–5 years



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ABSTRACT

Study Design: Cross-sectional.

Introduction: The Functional Dexterity Test (FDT) is a timed pegboard hand dexterity test. Normative data have been developed primarily in adults with some studies in the pediatric population. The present study will complement the existing pediatric data and make the FDT a stronger assessment for use in this population.

Purpose of the Study: The primary aim of this study was to collect normative data in typically developing children aged 3–5 years in the Greater Montreal area; the secondary aim was to evaluate the intrarater and interrater reliabilities of the FDT.

Methods: The FDT was administered to typically developing children aged 3–5 years, who were recruited from various geographical locations and socioeconomic status levels across the Greater Montreal area. Descriptive statistics, *t*-tests, and analysis of variance were used to compare age-gender groups. The intraclass correlation coefficient (ICC) was calculated to determine intrarater and interrater reliabilities.

Results: Normative data were collected from 267 children (137 females) from 18 daycares. Statistically significant differences in FDT scores were found across all age bands ($P < .01$). Total time decreased with increasing age ($P < .01$). No significant differences were found between genders. The FDT showed excellent interrater (ICC = 0.89–0.98) and intrarater (ICC = 0.83–0.99) reliabilities.

Conclusions: The clear and standardized pediatric instructions, scoring sheet, and normative data table developed in this study provide health care professionals with quick and easy tools to facilitate scoring and clinical interpretation of hand dexterity in preschool-aged children. Future studies should include school-aged children and adolescents from a larger geographic area.

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Introduction

Skilled hand use involves: the ability for one to have individual control over their fingers, a somatosensory system that can guide hand movements and the ability to react with an appropriate hand configuration from sensory information.¹ When children experience difficulties with any one of these skills, challenges can permeate in simple daily tasks involving picking up small objects between the thumb and index fingers,¹ such as when playing with small toys, and manipulating buttons and zippers during dressing tasks. As children

develop and continue to experience difficulties with fine motor tasks, their overall independence and ability to participate in the activities of daily living and school become further limited.

Several dexterity tests in pediatrics exist, including the Jebsen-Taylor Test, Purdue Pegboard Test, Box and Blocks Test, 9-Hole Peg Test, Grooved Pegboard Test, Sollerman Hand Function Test, and the Moberg Pickup Test. The Functional Dexterity Test (FDT) is an assessment for hand dexterity in both pediatric and adult populations. It is a timed pegboard test, which quickly allows clinicians to evaluate a patient's functional hand dexterity.² Standardized equipment for the FDT includes a square wooden pegboard (20.6 × 20.6 × 3.7 cm) with 16 peg holes (diameter = 2.5 cm; depth = 3 cm) that are organized in 4 rows of 4 with 2 cm of space between each row. Each peg hole contains a wooden peg (diameter = 2.2 cm; length = 4 cm) with a black- and white-colored face on each end. Patients are instructed to turn all the pegs over as quickly as

The authors Sabrina Curatolo, Marine Leblanc, Cristina Patulli, Tiffany Tang, and Joanie Tremblay provided equal contribution to this study.

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possible, completing each row in a zigzag fashion.² This is administered first with the patient's dominant hand, followed by their nondominant hand.

The FDT has several advantages over the aforementioned hand dexterity evaluations. First, the FDT has the strongest psychometric properties in the adult population when compared to other existing dexterity tests.³ Yet, this remains to be established in the pediatric population. More specifically, the FDT discriminated "intrinsic manipulative movements" better than the Jebsen-Taylor Test.⁴ 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.⁵

The FDT has been successfully norm-referenced for adults.⁶ Considering the benefits the FDT provides for the pediatric population, researchers have shown interest in developing pediatric norms for this evaluation. Preliminary norms have been developed with small sample sizes affecting generalizability.^{5,7} Additionally, the previous studies did not consider socioeconomic status (SES). Indeed, research has demonstrated that SES is associated with a wide array of outcomes in children, including overall health, cognitive, language, and motor development.^{8,9} These effects begin prior to birth and continue into adulthood.⁸ Therefore, sampling children from diverse SESs is important to construct valid FDT norms. Due to the quick administration time ideal for younger patients, and the convenient and easily reproducible testing equipment, the FDT is a useful tool for occupational therapists (OTs) in pediatric settings.

The primary purpose of this study was to develop normative data for the FDT in typically developing children aged 3–5 years in the Greater Montreal area. It was hypothesized that the time required to complete the FDT would decrease with increasing age: specifically, 3-year-olds would score slower than 4- and 5-year-olds, and 5-year-olds would score the fastest FDT times. It was also hypothesized that girls would score better than boys in this age group, as described in the study by Taylor et al.¹⁰ The secondary purpose of this study was to measure intrarater and interrater reliabilities of the FDT. It was hypothesized that the ICC will be moderate to high, denoting acceptable agreement between raters and within the same rater.

Methods

Participants

When developing norms, a sample of 50–75 participants per group is recommended.¹¹ In a pediatric population, it is essential to have normative data for each age group due to the functional changes occurring in child development. A power analysis was conducted, indicating that a sample size of 64 children per age band (3, 4, and 5 years) is appropriate in order to detect a moderate effect size (0.25) at 80% power with an alpha of 0.05. This can further be divided by gender (32 females and 32 males) creating a total of 6 groups and $n = 192$. Portney and Watkins¹² indicate that this number of participants is appropriate to detect significant differences in scores between age and gender groups in typically developing children. The present study used 1-year age bands as previous research conducted by Lee-Valkov et al.⁷ indicated that the mean performance between each year band (3, 4, and 5 years) was significantly different ($P < .01$).

The study received approval from the McGill Institutional Review Board. Children were recruited from a list of daycare facilities randomly selected from the Greater Montreal area using a public online directory, as well as a map with their postal codes and

associated incomes. Income was divided into 6 levels, where neighborhoods defined as level 1 have a median family income over \$90,000, level 2 from \$80,000–90,000, level 3 from \$70,000–80,000, level 4 from \$60,000–70,000, level 5 from \$50,000–60,000 and level 6 under \$50,000.¹³ Postal codes were used as a proxy for SES in order to ensure a representative sample. Daycares representing various boroughs of Montreal generated from the list were randomly selected and contacted by telephone to participate in the study. Once authorization was received from the daycare director, the investigators coordinated an initial visit to the facility to distribute packages to parents. Each package included (1) 1 information flyer, (2) 1 consent form, and (3) 1 short medical questionnaire. Signed consent, as well as completed medical questionnaire by the parent, was mandatory prior to determining eligibility of participants. Documents were provided in both English and French.

Eligibility

Three- to 5-year-old typically developing children were eligible to participate in the study. "Typically developing" was defined in this study as a child who is not under investigation nor has any confirmed diagnosis of an intellectual impairment, developmental disability, significant behavioral problems, motor impairment, or a congenital or acquired malformation of the upper extremities. All inclusion/exclusion criteria were gathered from the medical questionnaires, which were reviewed by the research team. Exclusion criteria included diagnosis or current investigation for aforementioned issues, receiving active occupational therapy (OT), speech and/or physical therapy services, and additional assistance in/outside of their daycare setting. Potential participants previously under investigation for delay in any sphere of development but with negative results or those who previously consulted specialized services and were discharged were included in the study. These selection criteria were sufficiently inclusive to ensure that all range of typical development was captured within the sample.

Testing procedures

English and French versions of the FDT assessment instructions were standardized through a forward-backward translation process prior to administration to maximize consistency and to reduce sources of measurement error.¹⁴ Grammar was verified by a French-speaking experienced occupational therapist (Appendix 1). A scoring sheet was also developed to facilitate the recording of participant performance during administration of the FDT (Appendix 2).

Each participant was evaluated by an OT master student with the FDT. Anglophone examiners evaluated the English-speaking 3- to 5-year-old children, and Francophone examiners led the assessment for French-speaking 3- to 5-year-old children. Each participant's FDT performance was videotaped to facilitate scoring. The FDT was conducted using a square wooden pegboard with 15 pegs. Chairs and desks that were available at the daycares were used by the evaluators, where children were asked to be seated so that at least 3 quarters of their thighs were on the seat pan, with the elbows at approximately a 90-degree angle to the desk and no more than 10 cm away. Children were given the opportunity to adjust their chair's position. Testing occurred in a safe and non-threatening environment (a small classroom or office within the daycare), with minimal distractions, good lighting, and with input from the daycare educator for scheduling a time where the children were most receptive to participate (eg, before/after snack time and after nap time). In order to ensure optimal interaction between the evaluators and the participants, initial contact with the participants was done through daycare educators. Time was granted prior to

testing so that the children may familiarize themselves and be at ease with the examiner. A video camera was set up behind the evaluator in a minimally distracting location, and recordings were then used for scoring. Any child that cried or resisted testing despite the examiners' best attempts was excluded from the study. Total testing time did not exceed 10 minutes.

Administration of the FDT

Prior to the beginning of the assessment, a paper and pen were positioned on the desk in front of the child, and he/she was asked to draw a ball. The hand naturally used by the child without prompting was recorded as the dominant one. The examiner then demonstrated the test by turning the first 2 rows of pegs in the proper sequence. The participant practiced by turning the first 2 rows with the dominant hand, and then the test was timed. This was followed with a practice and timed test for the nondominant hand. Although participants are required to complete a full board during the practice trial in the previous studies, the present study required participants to complete a 2-row trial given the decreased attention span of this age group.^{2,5,7} During the practice round, children were provided reminders if they performed a penalty, which included: supinating, touching the board, or using the other hand. During the administration of the test, participants were only provided with 1 reminder when performing any of the defined penalties. If the participant dropped a peg, the time was stopped, and the peg was returned to its original position in the wooden pegboard. As soon as the child came in contact with the peg again, time was resumed and the test continued. Both hands were tested. Similar to the study by Lee-Valkov et al.,⁷ timed pediatric penalties were used. However, adult times were used to allow for future clinical applicability: a 5-second penalty for supination movement passed neutral, for touching the board and for using the other hand or body part to adjust the position of peg, and a 10-second penalty for dropping the peg and for switching hands while turning a peg (Appendix 3). The instruction to follow a zigzag pattern was only provided initially during the practice. However, children who did not follow a zigzag pattern were not penalized because children aged 3–5 years have a shorter attention span and are easily distractible.⁷ Verbal encouragements were provided throughout the test administration in order to increase a child's test speed and motivation. Two scores were obtained: (1) time in seconds to complete the test and (2) combined total time with penalty seconds added to the initial time.

Reliability

Prior to testing, intrarater and interrater reliabilities were assessed to ensure consistent scoring for all examiners. Each of the 5 master's of OT students participated in a rater training session led by an experienced occupational therapist. During this training, the various types of penalties were defined, and the pre-recorded performance of a child was scored by the 6 raters using the experienced occupational therapist as a reference. Scores among all raters were compared with any discrepancies in scoring discussed until a consensus was reached.

Following this scoring consensus, an initial round of scoring was commenced in which the performance of a convenience sample of 6 children were watched and scored by all 6 raters. The video performances were re-scored by the same raters 3 weeks later. Intrarater and interrater reliabilities were then assessed with ICCs.

Data analysis

All data were analyzed using IBM SPSS Statistics, version 23. To address the first objective of collecting normative data for the FDT,

the participants were grouped by 1-year age bands (whole years) and gender. The appropriateness of these subgroups was confirmed by performing independent *t*-tests between populations. To test assumptions of equal variance, Levene's test for equality of variances was used. The Shapiro-Wilks test was further used to assess the normality of the distributions. Descriptive statistics were used to calculate means and standard deviations of total time, total time plus penalties, and frequency of the type of penalties for each hand and each age group.

In addition, the data were also analyzed within and between age bands to determine if age could be used as a continuous or dichotomous variable. FDT scores (total time plus penalties in seconds) were compared between (1) age bands and (2) gender. For age bands, a 3-way analysis of variance (ANOVA) was carried out comparing FDT scores among all age bands, and a 6-way ANOVA was performed to compare scores among all age-gender subgroups. For gender, independent *t*-tests were used to compare FDT scores (total time plus penalties) between girls and boys of that age for dominant and nondominant hands separated by age bands. To determine where the significant differences between age/age-gender subgroups lay, Tukey and Duncan's post hoc *t*-tests were performed. As well, 1-way ANOVAs were performed to test for differences in FDT scores (total time plus penalties) between the participants from different SES groups for dominant and nondominant hands separated by age bands. To determine where the significant differences between SES groups lay, Tukey and Duncan's post hoc *t*-tests were performed.

For the second objective, ICC values were calculated for interrater and intrarater reliabilities between 6 raters. The interrater reliability was calculated from the first scoring session for all raters.

Results

Participant characteristics

Three hundred ninety participants from 18 daycares across the island of Montreal in boroughs of varying SES strata were recruited. Of these, 119 children were excluded as they did not meet study criteria, were unavailable, refused to complete the test, or were unable to follow test instructions (Fig. 1). The number of participants assessed from each daycare and the daycare's corresponding SES are presented in Table 1. The sample consisted of 271 children between the ages of 3 and 5 years 11 months, of which 134 were female (49.45%; Table 2). There were 30 left hand-dominant children (19 females) among all participants.

A normal distribution was found for the 4-year-old age band group. However, using all original data collected, a normal distribution was not observed for 3 and 5-year-olds due to the presence of outliers who completed the test at a slower speed. After removing three 3-year-old males and one 5-year-old male from the analysis, the Shapiro-Wilks tests were revisited and normality was confirmed for these distributions. Thus, results were obtained using $n = 87$ for 3-year-olds, $n = 108$ for 4-year-olds, and $n = 72$ for 5-year-olds (total $n = 267$).

FDT normative data

Statistically significant differences between dominant and nondominant hands were observed in the FDT test time after penalties between all age bands ($P < .01$). However, no statistically significant differences were observed between males and females for each age band. Therefore, means and standard deviations for the test time for dominant and nondominant hands, before and after assigned penalties, are presented by 1-year age groups in Table 3.

After performing Tukey's post hoc *t*-test, no statistically significant differences were found between males and females for each

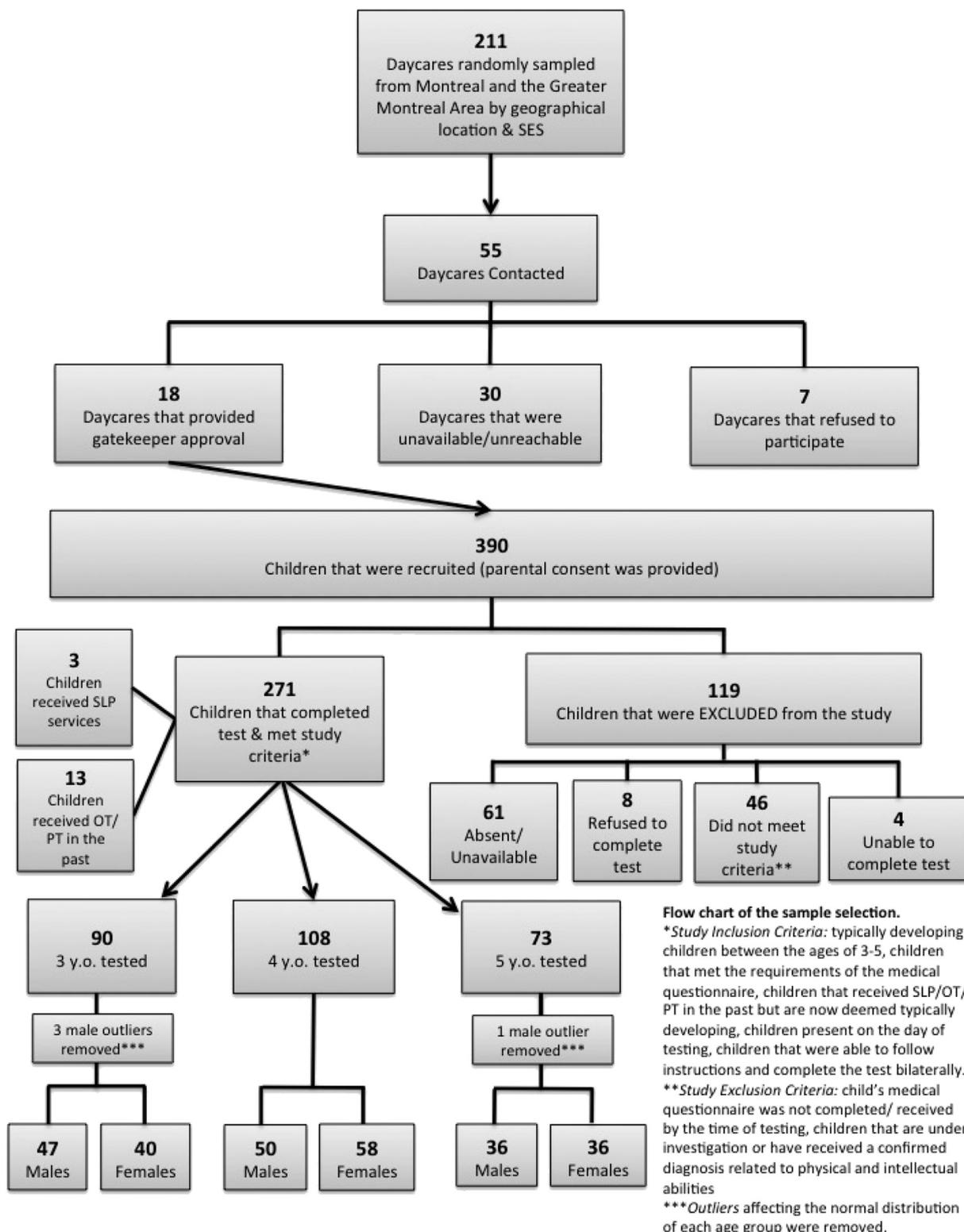


Fig. 1. Sample selection of daycares and participants. OT = occupational therapist; PT = Physical Therapy; SLP = Speech Language Pathology; SES = socioeconomic status; y.o. = years old.

age band (3-, 4-, and 5-year-old) with P values equal, respectively, to .986, .952, and .950 for the FDT times score with penalties for the dominant hand and .999, .949, and 1.000 for the nondominant hand.

Time with penalties decreased significantly for the dominant and nondominant hands with increasing age ($P < .01$).

Scoring penalties

The frequency of each type of penalty was calculated with both dominant and nondominant hands for each age group (Figs. 2 and 3). All 3-, 4-, and 5-year-old participants incurred penalties except for 1 female aged 5.01 years old.

Table 1
Participating daycares, socioeconomic status of borough and number of participants.

Daycare	Borough	SES ^a	Participants (n)
Daycare 1	Ville Marie/Griffintown	1	12
Daycare 2	Beaconsfield	1	27
Daycare 3	Kirkland	2	13
Daycare 4	TMR	2	15
Daycare 5	Baie-D'Urfé	2	24
Daycare 6	Outremont	3	27
Daycare 7	Côte des Neiges/Notre-Dame-de-Grâce	4	5
Daycare 8	Roxboro	4	5
Daycare 9	Côte St-Luc	4	15
Daycare 10	Anjou	5	10
Daycare 11	Laval	5	12
Daycare 12	LaSalle	5	22
Daycare 13	Hochelega-Maisonneuve	6	12
Daycare 14	Lachine	6	12
Daycare 15	Verdun	6	12
Daycare 16	Borough le Sud-Ouest	6	15
Daycare 17	Longueuil	6	16
Daycare 18	Snowdon	6	17
	Total		271

SES = socioeconomic status.

Level 1: over \$90,000; level 2: \$80,000-90,000; level 3: \$70,000-80,000; level 4: \$60,000-70,000; level 5: \$50,000-60,000; and level 6: under \$50,000.

^a SES is divided into 6 levels based on the median family income of the area.

In all age bands, touch board was the most common penalty incurred, followed by supination and using one's other hand or body part to adjust the peg. The penalty associated with switching hands was incurred most often in the 3-year-old group. A lower frequency of incurred penalties was observed with increased age and also when using one's dominant hand.

Socioeconomic status

Thirteen participants attending daycares from the lowest SES level (level 6) were excluded as they did not meet the selection criteria (eg, were followed in OT, physical therapy, or speech language therapy at the time of the study), followed by six participants from SES level 2, three participants from SES level 5, and two from SES levels 1 and 4. No statistically significant differences were observed between FDT scores (total time plus penalties).

Interrater and intrarater reliabilities of the FDT

The FDT showed excellent values for both interrater (ICC = 0.89-0.98) among the 6 raters and intrarater (ICC = 0.83-0.99) reliabilities with penalties over a 3-week period.

Discussion

The overall aim of this cross-sectional study was to develop normative data for the FDT in typically developing children aged 3-5 years in a large multicultural metropolis. The eligibility criteria were selected to ensure that our sample captured typically developing children, such that a child receiving therapy at the time of the study for, with a diagnosis of, or under investigation for a developmental condition (eg, speech and language impairment, motor delay, and so on) was excluded from the study. Developmental language impairment has been linked to the presence of considerable motor impairments.¹⁶ This exclusion criterion was provided to account for the variability in language development often present during preschool years and its possible influence on motor development.

Our findings corroborate the hypothesis that older children would perform better than younger children. However, in contrast to our initial hypothesis, females and males performed similarly, and so, we were unable to stratify the norms by gender. Providing norms that are not gender specific is consistent with the findings of the previous studies using the FDT in both the pediatric and adult populations.^{2,5,7} Contradiction exists within the literature with regards to gender differences in preschool children in the areas of fine motor development.¹⁵ Our findings suggest that in-hand manipulation represents a minute component of dexterity, which is not different between preschool males and females using the FDT. As expected, overall test times using the dominant hand were faster than those using the nondominant hand. In children especially, the emergence of dominance allows for one hand to have an active role during functional bimanual tasks such as manipulating small objects, while the other can assist.⁷ Our findings confirm the conclusions of previous pediatric studies using the FDT,^{5,7} which may indicate increased functionality when a child establishes hand dominance.

The present study has undertaken a larger sample size showcasing a variety of SESs to make it more representative to a Canadian population. SES was used as a parameter to ensure a representative sample in this study. Although higher SES has been shown to be associated with greater exposure to educational and play opportunities that may promote development,¹⁷ generally no significant differences were found when comparing FDT times with the SES levels associated with the participants' daycares. However, our findings provide grounds for further exploration of the relationship between development of hand dexterity and social class, as half of those excluded from the study (that were either followed in therapy or had a diagnosis) were from the lowest SES bracket.

The normative values developed in the present study without penalties are similar to those found in the previous study with typically developing children aged 3-5 years ($n = 63$).⁷ Although not calculated in Gogola et al.,⁵ normative values with penalties in the present study ($n = 267$) are consistent to Lee-Valkov et al.⁷ with typically developing children aged 3-17 years ($n = 175$). As expected, the normative values in the present study increased with penalties for the 3 age groups, with a high standard deviation suggesting that in-hand manipulation, a form of precision handling in which an object is adjusted within the hand after it is grasped,¹⁸ largely varies in preschool-aged children. In-hand manipulation skills are mostly developed by 3 years of age and extend beyond 6 years of age.^{19,20} In this study, 3-year-olds presented with the largest mean and standard deviation, which may be associated to the FDT requiring translation (moving objects from fingertips to palm of hand or retrieving objects from palm to fingertips) and complex rotation (using the thumb and fingers to turn an object end over end) in-hand manipulation skills. Consistent with the previous studies, children in the 3-year-old age band were observed to have difficulty removing pegs one at a time from storage and placing them in a pegboard, as well as rotating a peg without the use of an external surface (eg, body part and pegboard) for support.^{20,21} Variability of in-hand manipulation skills may likely be associated to differences in the biomechanics of the hand, as well as neuromotor maturation.²⁰ The large standard deviation values in our study may also be associated to the short attention span of this age group,⁷ as 3-year-olds exhibited greater difficulty following instructions, which increased the test time. Although variability in the penalties was observed in our sample, it represented a quarter of the mean, which is comparable to previous normative values for the Purdue Pegboard Test.²² Variability decreases with increasing age, which is consistent with typical development and amelioration of in-hand manipulation skills.¹⁹

Concurrent with the secondary aim of this study, excellent interrater (ICC = 0.89-0.98) and intrarater (ICC = 0.83-0.99) reliabilities among the 6 raters (5 examiners and 1 experienced

Table 2
Analysis of variance for the FDT times with penalties between and within age band

Dependent variable	(I) Age-gender subgroup	(J) Age gender subgroup	Mean difference (I–J) (s)	Standard error (s)	Significance value	95% confidence interval		
						Lower bound	Upper bound	
FDT time dominant hand with penalties	3-y-old males	3-y-old females	4.547	6.896	.986	–15.25 to 24.34		
		4-y-old males	25.882*	6.588	.002	6.97–44.80		
		4-y-old females	20.455*	6.800	.034	0.93–39.98		
		5-y-old males	40.869*	7.364	.000	19.73–62.01		
		5-y-old females	34.175*	7.364	.000	13.03–55.32		
	3-y-old females	3-y-old males	–4.547	6.896	.986	–24.34 to 15.25		
		4-y-old males	21.335*	6.291	.010	3.27–39.40		
		4-y-old females	15.908	6.512	.146	–2.79 to 34.60		
		5-y-old males	36.322*	7.100	.000	15.94–56.70		
		5-y-old females	29.628*	7.100	.001	9.24–50.01		
	4-y-old males	3-y-old males	–25.882*	6.588	.002	–44.80 to –6.97		
		3-y-old females	–21.335*	6.291	.010	–39.40 to –3.27		
		4-y-old females	–5.427	6.186	.952	–23.19 to 12.33		
		5-y-old males	14.988	6.801	.240	–4.54 to 34.51		
		5-y-old females	8.293	6.801	.827	–11.23 to 27.82		
	4-y-old females	3-y-old males	–20.455*	6.800	.034	–39.98 to –0.93		
		3-y-old females	–15.908	6.512	.146	–34.60 to 2.79		
		4-y-old males	5.427	6.186	.952	–12.33 to 23.19		
		5-y-old males	20.414*	7.007	.044	0.30–40.53		
		5-y-old females	13.720	7.007	.369	–6.40 to 33.84		
	5-y-old males	3-y-old males	–40.869*	7.364	.000	–62.01 to –19.73		
		3-y-old females	–36.322*	7.100	.000	–56.70 to –15.94		
		4-y-old males	–14.988	6.801	.240	–34.51 to 4.54		
		4-y-old females	–20.414*	7.007	.044	–40.53 to –0.30		
		5-y-old females	–6.694	7.555	.950	–28.39 to 15.00		
	5-y-old females	3-y-old males	–34.175*	7.364	.000	–55.32 to –13.03		
		3-y-old females	–29.628*	7.100	.001	–50.01 to –9.24		
		4-y-old males	–8.293	6.801	.827	–27.82 to 11.23		
		4-y-old females	–13.720	7.007	.369	–33.84 to 6.40		
		5-y-old males	6.694	7.555	.950	–15.00 to 28.39		
	FDT time nondominant hand with penalties	3-y-old males	3-y-old females	3.068	7.665	.999	–18.94 to 25.08	
			4-y-old males	25.404*	7.324	.008	4.38–46.43	
			4-y-old females	19.285	7.559	.113	–2.42 to 40.99	
			5-y-old males	38.886*	8.186	.000	15.38–62.39	
			5-y-old females	39.692*	8.186	.000	16.19–63.19	
		3-y-old females	3-y-old males	–3.068	7.665	.999	–25.08 to 18.94	
4-y-old males			22.337*	6.993	.019	2.26–42.41		
4-y-old females			16.217	7.239	.223	–4.57 to 37.00		
5-y-old males			35.819*	7.892	.000	13.16–58.48		
5-y-old females			36.624*	7.892	.000	13.97–59.28		
4-y-old males		3-y-old males	–25.404*	7.324	.008	–46.43 to –4.38		
		3-y-old females	–22.337*	6.993	.019	–42.41 to –2.26		
		4-y-old females	–6.119	6.876	.949	–25.86 to 13.62		
		5-y-old males	13.482	7.561	.478	–8.22 to 35.19		
		5-y-old females	14.287	7.561	.411	–7.42 to 35.99		
4-y-old females		3-y-old males	–19.285	7.559	.113	–40.99 to 2.42		
		3-y-old females	–16.217	7.239	.223	–37.00 to 4.57		
		4-y-old males	6.119	6.876	.949	–13.62 to 25.86		
		5-y-old males	19.601	7.789	.123	–2.76 to 41.96		
		5-y-old females	20.407	7.789	.096	–1.95 to 42.77		
5-y-old males		3-y-old males	–38.886*	8.186	.000	–62.39 to –15.38		
		3-y-old females	–35.819*	7.892	.000	–58.48 to –13.16		
		4-y-old males	–13.482	7.561	.478	–35.19 to 8.22		
		4-y-old females	–19.601	7.789	.123	–41.96 to 2.76		
		5-y-old females	0.806	8.399	1.000	–23.31 to 24.92		
5-y-old females		3-y-old males	–39.692*	8.186	.000	–63.19 to –16.19		
		3-y-old females	–36.624*	7.892	.000	–59.28 to –13.97		
		4-y-old males	–14.287	7.561	.411	–35.99 to 7.42		
		4-y-old females	–20.407	7.789	.096	–42.77 to 1.95		
		5-y-old males	–0.806	8.399	1.000	–24.92 to 23.31		

FDT = Functional Dexterity Test.

* Indicate the significance of $P < .05$.

occupational therapist) was established and maintained after a 3-week period, allowing all 5 examiners to collect normative data. This is similar to the good-to-excellent interrater ($ICC = 0.73–0.88$) and intrarater ($ICC = 0.72–0.90$) reliabilities established with the adult population.² Our study supports the reliability of using the FDT with penalties in the pediatric population provided that training and regular practice is maintained to maximize consistency between testing periods.

The penalties applied in this study were utilized in order to measure the quality of hand movement given that time alone is not a measure of dexterity.² In all age bands, touch board was found to be the penalty most often performed, with supination being the second most frequent. When children did not supinate, they performed other penalties like using their body to compensate for limited finger movements. The FDT requires a dynamic tripod grasp.² We observed that many participants often performed the test using an immature

Table 3

Means and standard deviations for the FDT times with and without penalties in typically developing children aged 3–5 years in Montreal, Canada

Age band	Time with penalties (s)		Time without penalties (s)	
	Dominant hand; mean (SD)	Nondominant hand; mean (SD)	Dominant hand; mean (SD)	Nondominant hand; mean (SD)
3 y old (n = 87)	119.22 (36.28)*	133.37 (38.66)*	43.53 (9.72)	47.73 (10.38)
4 y old (n = 108)	98.31 (31.57)*	112.45 (34.22)*	40.81 (8.01)	44.53 (8.87)
5 y old (n = 72)	84.15 (26.64)*	95.74 (33.32)*	36.60 (8.13)	38.31 (7.91)

FDT = Functional Dexterity Test; SD = standard deviation.

*P < .01.

grasp, which may have affected their overall performance. The frequencies of penalties suggest that mature grasp and movement patterns develop over time²³ and may not be reflective of those observed in preschool-aged children. Previous studies have suggested that using penalties may not be appropriate with preschool-aged children because of their short attention span and distractibility.^{5,7} However, the use of penalties allows clinicians to track the performance of a child longitudinally as our results indicate that development will account for improvement in scores over time. In addition, using adult penalties also serves as a comparison with norms of other age bands in future studies.

In previous studies, normative values were presented using speed or time as a parameter to measure dexterity.^{5,7} The present study acknowledges the work of previous studies and has chosen to present the normative values using the parameter of time in a table format. While speed is important to consider for participants who do not finish the testing board, in our experience, all children completed the testing board, and thus, we were able to capture a universal comparison between children. In collaboration with OTs working in an acute rehabilitation setting, assessments evaluating dexterity (eg, Jepsen-Taylor Test of Hand Function, 9-Hole Peg Test, Purdue Pegboard Test, and so on) that present data in a table format including means and standard deviations are regularly used in practice. In addition, the speed of use and easy interpretation of a table may cater to a variety of users. Previous work on the FDT presented normative

values in a growth chart, which makes the visualization of the expected speed for any given age easier by using a continuous age scale.⁵ The present study recognizes these benefits and will compliment what has already been done previously. Future direction would be to combine a growth chart and table of normative values to provide clinicians, who have individual preferences and who work in various practice areas, more options when using the FDT.

Study limitations

There were several practical and methodological limitations that were considered when conducting the study. First, the administration procedure and scoring changes that were adjusted for the pediatric population affected the standardization of the FDT. For example, the present study required that the children complete two full rows instead of a full board during the practice trial due to the decreased attention span of this age group. However, it is suggested by Lee-Valkov et al⁷ that the learning effect is eliminated after completing a full board trial. Therefore, this may have affected the consistency of the present study normative data. Some additional verbal instructions and visual demonstrations were also provided to those participants having difficulties understanding the instructions. To reinforce standardization of the assessment, a prepared script was developed and used by each of the examiners. Second, although a high ICC (>0.90) among examiners was

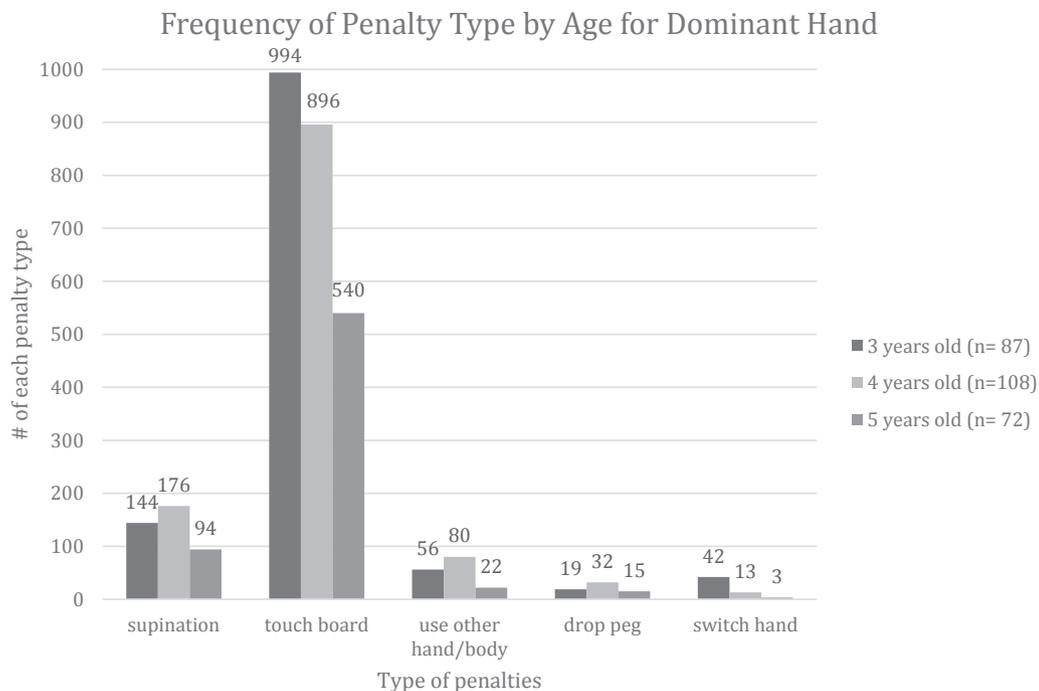


Fig. 2. Comparing the type of penalties by age for dominant hand.

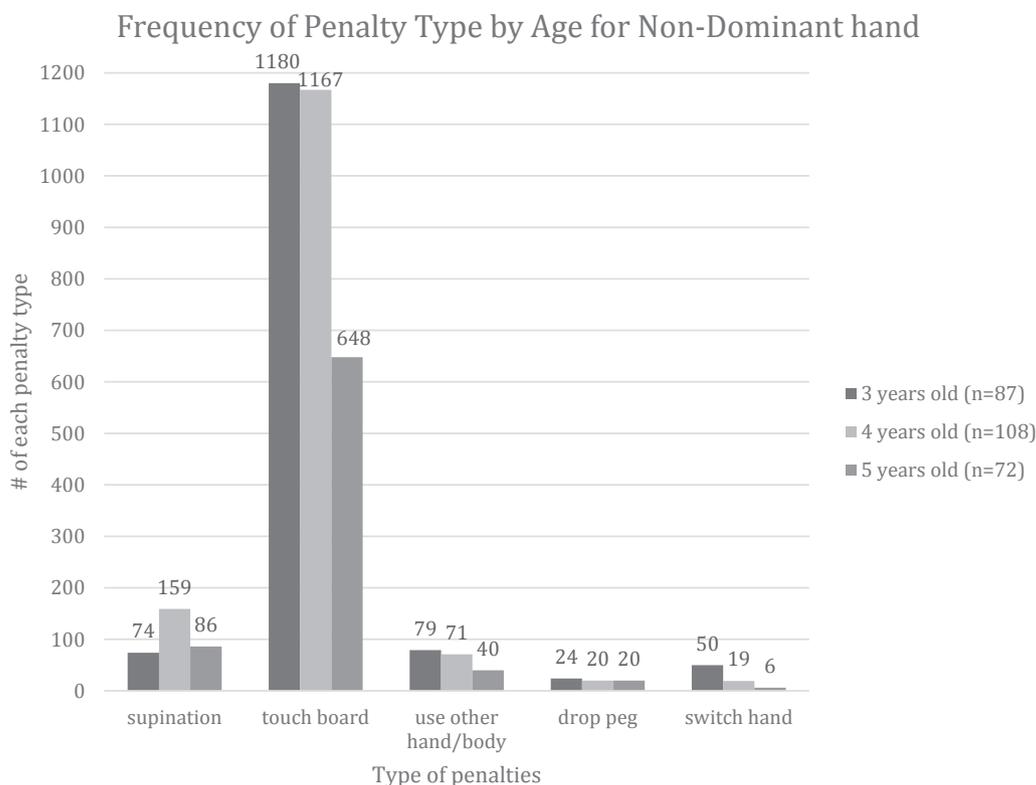


Fig. 3. Comparing the type of penalties by age for nondominant hand.

maintained, some penalty guidelines continued to remain subjective (eg, touch board). Furthermore, scoring using the videos sometimes prevented the ability to decipher between penalty types (eg supination vs using another body part). To exercise greater scoring consistency among examiners regarding the penalty types, the research team used a training video to practice administering and scoring the FDT prior to the data collection phase.

The environment in which the test was performed differed between daycares, which may have influenced child performance and the reliability of the data. Testing locations varied from private rooms with minimal distractions to a small space within the classroom setting with a significant noise level. To maintain minimal distractions and an optimal testing environment, examiners positioned participants facing away from visual distractions and reinforced eye contact with the child. At times, the staff were present during test administration. Nevertheless, completing the test in the child's familiar daycare setting may have minimized any stress associated with the test performance. Moreover, the equipment available at the daycare, such as the chair and desk size/height was not always suitable for the participant to achieve the appropriate posture/positioning for test administration. Materials such as cushions and books were used to attain proper positioning during the FDT administration. Generalizability of the study may be limited as the sample was recruited from the Greater Montreal area. However, norms developed through this study included a large representative sample of preschool-aged children from a major urban area spanning all 6 SES levels.

Conclusion

Clinical contributions from this present study include clear and standardized instructions for administering the FDT and a FDT scoring sheet adapted for the pediatric population. The scoring

sheet developed and used in this study, as well as the normative data table, provide health care professionals working in pediatric settings with a quick and easy tool to facilitate scoring and clinical interpretation. In turn, regular training is recommended for evaluators to maintain reliability when using penalties with the FDT in the pediatric population. The present study's procedures and normative values for preschool-aged children serve as a basis for the development of norms for school-aged children and adolescents in future studies. However, to ensure consistency with normative data, a full board practice trial is recommended in future studies. The training video and scoring instructions are available upon request.

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Quiz: # 595

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- # 1. The FDT is
 - a. an outdated test of manual dexterity
 - b. a timed peg board test of manual dexterity
 - c. a recently (2017) described test of manual dexterity
 - d. an acronym for the Field Digital Triad
- # 2. The original FDT was developed by
 - a. Krotowski et al
 - b. MacDermid et al
 - c. Michlovitz et al
 - d. Aaron et al
- # 3. One of the most important results of the study was the
 - a. the assessment of a sensibility scale administered immediately prior to the administration of the FDT itself

- b. production of a video instructing therapists in the proper administration of the FDT
 - c. development of normative data for this age group
 - d. distinction of data between dominant and non-dominant hands
- # 4. The FDT showed
 - a. the need for only CHTs to administer it
 - b. high inter-rater and intra-rater reliability
 - c. high inter-rater, but low intra-rater reliability
 - d. high intra-rater, but low inter-rater reliability
 - # 5. The authors strongly recommend training for clinical personnel who are going to administer the FDT with pre-school-aged patients
 - a. true
 - b. false

When submitting to the HTCC for re-certification, please batch your JHT RFC certificates in groups of 3 or more to get full credit.

Appendix 3. Pediatric penalties

Penalty	Description	Time added
Supination	Any time the wrist moves beyond a neutral position.	5 s
		
Touch board	Any time the peg comes in contact with the board (this includes resting the peg on the board to turn it).	5 s
		
Assist with other hand/body	Whenever the child uses their body part, other hand, or external surface to adjust a peg.	5 s
		
Switch hand	If the child places the peg into the pegboard with the hand that isn't being tested.	10 s
		
Drop peg	If the peg is dropped outside of the area covered by the 3 adjacent pegs or off of the board.	10 s
		