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Assessing Dexterity Function: A Comparison of Two Alternatives for the NIH Toolbox

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Abstract

Study Design—Clinical measurement.

Introduction—Manual dexterity is an important aspect of motor function across the age span.

Purpose of the Study—To identify a single measure of manual dexterity for inclusion in the National Institutes of Health (NIH) Toolbox Assessment of Neurological and Behavioral Function.

Methods—A total of 340 subjects participated in our study. Two alternatives, Rolyan® 9-Hole Peg Test (9-HPT) and Grooved Pegboard test, were compared by assessing their score range across age groups (3–85 yr) and their test–retest reliability, concurrent, and known groups validity.

Results—The 9-HPT was a simple, efficient, and low-cost measure of manual dexterity appropriate for administration across the age range. Test–retest reliability coefficients were 0.95 and 0.92 for right and left hands, respectively. The 9-HPT correlated with Bruininks-Oseretsky Test (BOT) of Motor Proficiency, dexterity subscale, at -0.87 to -0.89 and with Purdue Pegboard at -0.74 to -0.75 . The Grooved Pegboard had good test–retest reliability (0.91 and 0.85 for right and left hands, respectively). The Grooved Pegboard correlated with BOT at -0.50 to -0.63 and with Purdue Pegboard at -0.73 to -0.78 . However, the Grooved Pegboard required longer administration time and was challenging for the youngest children and oldest adults.

Conclusions—Based on its feasibility and measurement properties, the 9-HPT was recommended for inclusion in the motor battery of the NIH Toolbox.

Level of Evidence—NA.

Manual dexterity (hand function) is an individual's ability to coordinate the fingers and manipulate objects in a timely manner. Such ability greatly impacts a person's performance in daily activities, such as self-care tasks, typing on a computer keyboard, messaging on a cell phone, completing work-related tasks, and engaging in leisure activities. As a child, fine hand skills are found to be correlated with participation in academic activities and quality of handwriting.^{1–4} As an adult, manual dexterity aptitude serves as an indicator for work performance (e.g., machine workers, dentists, surgeons).^{5,6} Decline in manual dexterity is a common phenomenon in older adults and is associated with performance of activities of daily living and independent living.^{7,8} Through the life span, dexterity may be lost because of injury or disease, which results in varied degree of activity limitations and participation restrictions.^{9–11} There is, however, a lack of consistency and consensus as to how to best measure dexterity in clinical practice and research across the age span.

Major measurement initiatives, such as the National Institutes of Health (NIH) Toolbox for the Assessment of Neurological and Behavioral Function,¹² have underscored the need for standard performance-based measures that can be administered efficiently across the age span. The intent of the NIH Toolbox is to develop an assessment battery for use in epidemiologic, longitudinal, and clinical research that is psychometrically robust while simultaneously being brief, portable, low cost, and easy to administer. Manual dexterity was identified as a core construct for inclusion in the NIH Toolbox based on the findings from a field survey of experts in epidemiologic and longitudinal health research and in-depth interviews with experts in motor function.¹² The purpose of this study was to evaluate manual dexterity measures for inclusion in the NIH Toolbox based on their feasibility and measurement properties.

METHODS

Instrument Identification

In a preliminary survey, we identified 205 existing measures of motor function (i.e., locomotion, balance, dexterity, endurance, and muscle strength). Of the 205 measures identified, 128 were eliminated because they were self-report, designed for a specific disease population, or not purely measuring-proposed Toolbox dexterity subdomains. The remaining 77 measures of motor function (18 locomotion, 21 balance, 17 dexterity, 11 endurance, and 10 strength) went through in-depth review by the project team. The *a priori* criteria for inclusion in the NIH Toolbox, proposed by the Toolbox steering committee, included being feasible for administration to people aged 3–85 years, brief to administer (<5 min), easy to administer and score, adequate in terms of test–retest reliability and concurrent validity with age-appropriate criterion measures, and able to discriminate between known groups. The investigation process resulted in two final dexterity candidate measures: Rolyan® 9-Hole Peg Test (9-HPT) (Sammons Preston) and Grooved Pegboard test (Lafayette Instrument

Company, Inc.). The 9-HPT was selected because it met the most inclusion criteria and the test was easy to administer in all age groups, especially younger children. Additionally, the time to administer the 9-HPT was brief as required for inclusion in the NIH Toolbox. The Grooved Pegboard was selected because it met the inclusion criteria and was able to measure higher level of dexterity function.

Subjects

Individuals were eligible for inclusion if they were aged between 3 and 85 years and healthy without major orthopedic or neurologic impairments. Individuals were excluded if they had severe cognitive or comprehension deficits that prevented them from following verbal commands and concurrent and/or confounding medical conditions (e.g., cardiopulmonary illness, musculoskeletal injury) that would render them unfit to participate.

A convenience sample of 340 subjects stratified across 10 age bands (3–4, 5–6, 7–9, 10–13, 14–20, 21–30, 31–45, 46–65, 66–75, and 76–85 yr) was recruited across three collaborating sites: the Rehabilitation Institute of Chicago, University of California, Los Angeles (UCLA), and University of Connecticut (UConn). A subsample of 53 subjects returned to the test site for a second session within two weeks from the first visit to evaluate test–retest reliability of the candidate measures. The age band stratification is not based on any existing age group classifications but rather based on the fundamental knowledge that the dexterity function changes rapidly as children grow older (thus requiring more narrow age bands for young children), remains relatively stable across the middle-age groups, and begins to deteriorate slowly when subjects get older (and thus wider age bands were given to the adults).

This study was approved by the institutional review boards at Northwestern University, NorthShore University Health Systems, UConn, and UCLA. Subjects completed age-appropriate consent procedures.

Measures

Both measures (i.e., 9-HPT and the Grooved Pegboard) are similar in that they include one-piece boards with molded concave dishes and holes for pegs; pegs are placed in holes using fingers. In addition, two age-appropriate dexterity measures were also administered (i.e., the Bruininks-Oseretsky Test (BOT) of Motor Proficiency Manual Dexterity Subtest and the Purdue Pegboard) (see Experimental Procedure and Statistical Analysis for the rationale).

The 9-HPT (Figure 1A) consists of a molded dish next to the 9-hole pegboard ($31 \times 26 \times 4$ cm) with nine plastic pegs (0.6 cm in diameter). The pegboard was positioned at midline. Subjects were instructed to sit on a height-appropriate chair, which ensures that the tabletop was at midchest level, and place and remove all nine pegs one at a time as quickly as possible; order of placement was not prescribed. The score was the total time in seconds to complete the task.

The Grooved Pegboard (Figure 1B) has an integrated design with a well above the pegboard holding grooved metal pegs. The pegboard has 25 grooved holes arranged in rows of five; the shape of each hole is identical, but the orientation varies so that subjects must rotate the peg to match the hole before they can be inserted. Subjects were instructed to put 25 pegs in the holes in a fixed order from side to side and from top to bottom. The final score was the total time in seconds to complete a trial. But children only did the first two rows.

The BOT Manual Dexterity Subtest has five items including making dots in circles, transferring pennies, placing pegs into a pegboard, sorting cards, and stringing blocks. Children were instructed to perform each task as quickly as possible for 15 seconds. The raw

scores were converted to a point score based on the BOT scoring sheet. The final score was the total point score representing the overall manual dexterity function.

The Purdue Pegboard consists of a test board, pins, collars, washers, and score sheets. Subjects were instructed to insert one pin at a time, starting with the top hole, in a vertical column as quickly as possible in a fixed time. The final score was the number of pins inserted. The test compiles five separate scores from the complete test procedures, including 1) right hand (30 s), 2) left hand (30 s), 3) both hands (30 s), 4) right + left + both hands, and 5) assembly (60 s). The subjects do not need to use tweezers to complete the Purdue but simply use their hands. Here, we used the R + L + both score (i.e., a combined score) to represent the overall dexterity function.

Experimental Procedure

Before the data collection, research staff were trained and certified to ensure standardized data collection across the three sites. The 9-HPT and the Grooved Pegboard tests were administered to each subject during a single testing session at one of the three collaborating research sites. For all the tests, subjects completed a practice trial plus two timed trials of each dexterity test starting with their dominant hand. Total time in seconds to complete a trial was recorded.

Children aged 3–9 years completed the “Kiddie” protocol of the Grooved Pegboard, which requires them to fill only the first two rows of the pegboard (i.e., 10 pegs). The protocol, described in the user manual, was used because concerns about their shorter attention span.

In addition, subjects completed two additional age-appropriate dexterity measures in the same session: 1) for children aged 3–14 years, the BOT—the manual dexterity subscale was administered and 2) for aged 15 years and older, the Purdue Pegboard was administered. The test order was randomized within the dexterity subdomain. We selected the best scores for each subject by each hand.

Statistical Analysis

We compared two alternatives, 9-HPT and Grooved Pegboard, by assessing their score ranges across age groups (3–85 yr) and their test–retest reliability, concurrent, and known groups validity.

To assess the feasibility of measuring dexterity across the life span, we plotted score distributions using box plots and inspected the minimum, maximum, average, and score range. To assess test–retest reliability, we calculated intraclass correlation coefficients between the first and second sessions using two-way random effects model with absolute agreement. For concurrent validity, we correlated measures with age-appropriate criterion measures (the BOT—dexterity subscale for children younger than 14 years or the Purdue Pegboard test [R + L + both] score for people aged 14 years or older) using Pearson correlation coefficients. To assess capacity to discriminate dexterity function, we assessed known groups validity in two ways: we compared 1) three age groups (3–14, 15–45, and 46–85 yr to represent children; young adults; and older adults groups); and 2) good or poor hand function groups decided by the scores on the BOT or Purdue Pegboard test. One-way measures analysis of variance (ANOVA) procedures were used to compare between groups. Dependent measures were scores on the selected dexterity candidates. Subjects were split into good hand function group, if their dexterity function as indicated by the BOT or Purdue Pegboard test was >50 percentile, or poor hand function group, if their dexterity function as indicated by the BOT or Purdue Pegboard test was <50 percentile.

RESULTS

A total of 340 subjects participated in our study. Six subjects were removed because they reported that they had a stroke or transient ischemic attack. An additional 29 subjects were removed because of missing data, including missing age ($n = 6$), missing handedness ($n = 2$), and incomplete data across multiple dexterity trials ($n = 21$). A total of 305 remaining subjects were included in the analyses.

Of subjects with incomplete data, 10 subjects were 3 or 4 years old, three subjects were 5 or 6 years old, and four were between 9 and 11 years old. Incomplete data stemmed from children not wanting to perform a second trial, being tired or sleepy on arrival, or appearing too frustrated to continue. Majority of the complaints were toward the Grooved Pegboard test. Additionally, one older subject had arthritis that severely limited his ability to perform and complete the task. The remaining subjects had unknown reasons.

Of 305 remaining subjects with complete dexterity data, the mean (standard deviation [SD]) age was 32 (26) years (minimum = 3 yr, maximum = 85 yr). Fifty-five percent were women. Most subjects (92%) were right hand dominant. Sixty-six percent were White, 14% were Asian, and 9% were Black in ethnicity. When responding to the general health question (rating scale 1–4), 48% reported excellent health, 37% reported very good health, 14% reported good health, and remaining 1% reported fair health.

Measuring Dexterity Across the Lifespan

Table 1 displays the average and SD of time to complete a trial of the 9-HPT and Grooved Pegboard test in seconds. On average, subjects spent 19 and 21 seconds completing a trial of the 9-HPT using their right and left hands, respectively. The average completion times for the Grooved pegboard were 42 (right hand) and 49 (left hand) seconds for children aged 3–9 years to complete the “Kiddie” version and 65 (right hand) and 73 (left hand) seconds for subjects aged 10 years and older.

Figure 2 shows the score distribution of the 9-HPT across 10 age bands when subjects used their right hand (*upper panel*) to perform the task. We also provided the score distribution while adjusting for hand dominance for subjects aged 5 years or older (*lower panel*). Figure 3 shows the score distribution of the Grooved Pegboard in the same format. Both figures showed the speed of dexterity improved until age 45 or so when the speed began to decline. Beginning at age 10, all subjects did the complete Grooved Pegboard test. This accounts for the increased time shown for subjects older than 10 years.

Test–Retest Reliability

For 9-HPT, the test–retest reliability coefficients and their 95% confidence intervals (in brackets) were 0.95 (0.93, 0.96) and 0.92 (0.90, 0.94) for right and left hands, respectively (all $p < 0.001$). For the Grooved Pegboard test, the test–retest reliability coefficients were 0.91 (0.84, 0.95) and 0.85 (0.81, 0.89) for right and left hands, respectively (all $p < 0.001$). Both tests demonstrated moderate to high test–retest reliability.

Concurrent Validity

For the 120 subjects who completed the BOT dexterity subscale, the scores ranged from 4 to 45 with a mean (SD) score 25 (9). For the 185 subjects who completed the Purdue Pegboard test, the scores ranged from 22 to 55 with a mean (SD) score 39 (6).

Results of concurrent validity of dexterity measures are shown in Table 2. In general, the 9-HPT had a higher correlation with the BOT—dexterity subscale. In contrast, the Grooved

Pegboard had a higher correlation with the Purdue Pegboard test. The results were within expectations because the BOT test was designed for children and included easier hand function tests. On the other hand, the Purdue Pegboard test was designed for the selection of employee in industrial occupations and therefore included more complex dexterity tasks, and thus less appropriate for children.

Known Groups Validity

One-way ANOVA results showed that the 9-HPT discriminated the age-related dexterity function well among children (age 3–14), young adults (age 15–45) and older adults (age 46–85) ($F = 38.4$, $df = 2$, $p < 0.001$ [right]; $F = 37.0$, $df = 2$, $p < 0.001$ [left]). Post hoc Scheffe tests showed significant differences from all three comparisons (all $p < 0.05$). Among children (age 3–14), the 9-HPT discriminated good (BOT >50 percentile) and poor (BOT <50 percentile) dexterity function as determined by BOT dexterity subscale scores ($F = 149.1$, $df = 117$, $p < 0.001$ [right]; $F = 123.5$, $df = 116$, $p < 0.001$ [left]). Similarly, in the adult sample (aged 15 years and older), the 9-HPT discriminated good (Purdue >50 percentile) and poor (Purdue <50 percentile) dexterity function determined by the Purdue Pegboard test ($F = 113.0$, $df = 183$, $p < 0.001$ [right]; $F = 112.2$, $df = 183$, $p < 0.001$ [left]).

To assess the known groups validity by age group using Grooved Pegboard, the scores for children aged 3–9 years were adjusted by multiplying 2.5 (because they only completed two rows instead of five). Oneway ANOVA results showed that the Grooved Pegboard test can discriminate the dexterity function by age groups ($F = 8.2$, $df = 2$, $p < 0.001$ [right]; $F = 33.1$, $df = 2$, $p < 0.001$ [left]). Post hoc Scheffe tests showed significant differences between all pairwise comparisons except that the comparison between young and older adults was insignificant ($p = 0.274$). Among children (aged 3–9 years), the Grooved Pegboard test discriminated between good and poor dexterity function ($F = 12.6$, $df = 77$, $p = 0.001$ [right]; $F = 16.4$, $df = 77$, $p < 0.001$ [left]) based on the BOT classification. The Grooved Pegboard test discriminated the good and poor dexterity function ($F = 73.4$, $df = 183$, $p < 0.001$ [right]; $F = 92.8$, $df = 183$, $p < 0.001$ [left]) classified by the Purdue Pegboard test.

DISCUSSION

The NIH Toolbox Assessment of Neurological and Behavioral Function¹² is a major measurement initiative funded by the NIH Neuroscience Blueprint. It is focused on developing a standard set of measures of motor, cognitive, sensory, and emotional health and function for use in epidemiologic and longitudinal research. The NIH Toolbox is intended to be brief, portable, easy to administer by lay administrators, and feasible for measuring dexterity across the life span. Given the importance of manual dexterity to both clinical practice and epidemiologic research, there is a need to include a valid measure of dexterity that met the NIH Toolbox constraints.

One challenge in selecting a measure of dexterity was the criterion of administration time (gives instructions and administers the test <5 minutes). Several more comprehensive dexterity batteries, such as the Purdue Pegboard test and the Roeder manipulative aptitude test, have longer administration times or multiple subscores and thus were excluded.

In this study, we assessed one of the most commonly used tools for assessing dexterity—the 9-HPT. The 9-HPT can be easily administered to measure dexterity in varied age groups. Norms for the 9-HPT have been published for children aged 5–10,¹³ 7–12,¹⁴ 4–19 years¹⁵ and adults aged 21–71 or older¹⁶ and 20–75+ years,¹⁷ which supported its use across the age span. In the study by Poole et al.,¹⁸ children of ages 4–5 on average spent 30 seconds to complete the 9-HPT using their dominant hand and 34 seconds using their nondominant hand. Individuals who are 18–19 years old completed the test faster (17 seconds). Based on

the studies by Grice et al.¹⁶ and Mathiowetz et al.,¹⁷ time to complete the 9-HPT increased from approximately 17 seconds at age of 21–25 to 20 seconds at age 55–60 and to 26 seconds at age of 71 and older. In our study, the mean completion time for the 9-HPT for the youngest subjects, aged 3–4 years, was 40 seconds. Adults aged 21–30 years had the shortest mean completion of 17 seconds, whereas for adults aged 76–85 years, the mean time was 24 seconds. These results demonstrate that the 9-HPT is quick and easy to administer across all ages.

Norms for the Grooved Pegboard test (age 5–60) are published in its user manual by Lafayette Instrument Company, Inc. Additional studies have examined Grooved Pegboard test in children at age 5 and 11,¹⁹ children aged 10–17 years,²⁰ and community-dwelling older individuals (ages 55–74).²¹ It is unclear if studies of children younger than 9 years used the “Kiddie” or standard protocols. To our knowledge, this is the first study that attempted to evaluate the Grooved Pegboard in people as young as 3 and older than 75 years. In our study, children aged 3 or 4 years had difficulty complying with the Grooved Pegboard protocol, both in terms of maintaining attention to task and following peg placement order. Based on the Grooved Pegboard user manual, 80–113 seconds was required to complete a trial. In our study, duration of 60–101 seconds was needed to complete an adult version trial. Thus, the estimated total time to complete three trials would exceed the 5-minute time criterion set by the NIH Toolbox steering committee.

Although the Grooved Pegboard has the capacity of assessing higher dexterity function, motor expert consultants to the NIH Toolbox expressed concerns about the cognitive and visual-perceptual task demands risked confounding manual dexterity with other aspects of neurobehavioral function. Similarly, task complexity and length may preclude accurate measurement in very young children. In contrast, although the 9-HPT is capable of assessing dexterity across the age groups, there were concerns about its simplicity thus its ability to distinguish dexterity function at the higher level.

Both the 9-HPT and the Grooved Pegboard demonstrated good and comparable test-retest reliability, concurrent, and known groups validity. The 9-HPT met more Toolbox criteria, including the ability to be used across the age span, and is therefore recommended as the measure of dexterity within the NIH Toolbox. The 9-HPT will be further validated in a larger and more diverse sample ages 3–85 as part of the NIH Toolbox “norming” phase, scheduled to begin in spring of 2011. Given the Grooved Pegboard’s documented sensitivity and use in neuropsychological testing batteries,²² the Grooved Pegboard is recommended as a supplemental Toolbox measure and will be further evaluated in NIH Toolbox “norming” phase in a subsample.

There are several challenging limitations of this study. First, the need to balance psychometric rigor and sensitivity with considerations of brevity, cost, ease of administration, and applicability across the life span challenged the research team to make compromises in the instrument recommendation process. Researchers with a scientific emphasis on hand function may choose to supplement the NIH Toolbox with more in-depth measures. As the NIH Toolbox is designed to encourage researchers to evaluate motor, cognitive, sensory, and emotional function in addition to their areas of interest, these compromises are deemed acceptable and appropriate. The evaluation of candidate measures was limited to two existing pegboard designs. As computer technology continues to advance, alternative pegboard designs that use digital touch screen and smart phone technology may emerge as viable alternatives to existing dexterity measures. Additionally, a convenience sample was recruited to participate in this study, and the majority was relatively active and healthy, including subjects in the 76–85 years age group. Therefore, our

reported results may indicate better performance than would be demonstrated in a broader population-based sample.

Lastly, there are concerns about analyzing the data based on right or left hand rather than hand dominance. First, this study is designed to evaluate manual dexterity measures for inclusion in the NIH toolbox based on their feasibility and measurement properties; it was not meant to generate normative values. Second, children as young as 3–4 years may not have well-developed handedness. In general, children may start to show the preference for the right or left hand when they are 2 or 3 years old. The developmental milestone for handedness is about 24 months (normal range: 18–30 mo). However, the exact developmental milestone when the children develop clear hand dominance is unknown. Hill and Khanem²³ examined the development of hand preference in children and demonstrated that younger children (4–5 years) showed weak hand preference in comparison to older children (8–11 years). As a result, we felt that it was not appropriate to analyze children's data (3–4 years) based on hand dominance. Third, of 305 remaining subjects with complete dexterity data, only 26 (8%) were left hand dominant (including two subjects who were 3–4 years old). We have reanalyzed the subjects based on hand dominance and found negligible differences between results analyzed based on hand dominance and simply based on right or left hand. For instance, subjects spent 19.3 (5.3) and 20.8 (6.3) seconds completing a trial of the 9-HPT using their right and left hands, respectively, and they spent 19.3 (5.3) and 20.8 (6.4) seconds based on their dominant and nondominant hands, respectively. The box plots of the 9-HPT based on these two methods were very alike (Figure 2). Similarly, subjects spent 58.7 (19.0) and 66.6 (22.7) seconds completing a trial of the Grooved Pegboard test using their right and left hands, respectively, and they spent 58.4 (18.8) and 66.9 (22.8) seconds based on their dominant and non-dominant hands, respectively. The box plots of the Grooved Pegboard test based on these two methods were almost the same (Figure 3). Besides the similarities in the averages and SDs of time to complete a trial, results of the test–retest reliability were similar as well. For 9-HPT, the test–retest reliability coefficients and their 95% confidence intervals were 0.95 (0.93, 0.96) and 0.92 (0.90, 0.94) for right and left hands, respectively (all $p < 0.001$) and were 0.95 (0.88, 0.93) and 0.94 (0.92, 0.95) for dominant and nondominant hands, respectively (all $p < 0.001$). For Grooved Pegboard test, the test–retest reliability coefficients were 0.91 (0.84, 0.95) and 0.85 (0.81, 0.89) for right and left hands, respectively, and were 0.94 (0.90, 0.96) and 0.92 (0.90, 0.94) for dominant and nondominant hands, respectively. Adjusting for hand dominance slightly improved the reliability estimates. For the evidence supporting concurrent validity, the 9-HPT correlated with BOT at -0.89 (right hand) and -0.87 (left hand) and with Purdue Pegboard test at -0.75 (right hand) and -0.74 (left hand). After adjusting for hand dominance, the 9-HPT correlated with BOT at -0.89 (dominant hand) and -0.86 (nondominant hand) and with Purdue Pegboard test at -0.75 (dominant hand) and -0.72 (nondominant hand). Lastly, all the known groups validity was supported, no matter which methods were used.

CONCLUSION

The 9-HPT is recommended as the preferred measure of dexterity in the NIH Toolbox Assessment of Neurological and Behavioral Function, and the Grooved Pegboard test is recommended as a supplemental Toolbox measure. In the next phase of the NIH Toolbox project, we will recruit a larger and more diverse sample to establish norms for all of the NIH Toolbox measures across the age span.

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FIGURE 1.
Candidate dexterity measures. (A) Rolyan® 9-Hole Peg Test. (B). Grooved Pegboard test.

FIGURE 2.

Box plot of the Rolyan® 9-Hole Peg Test times (seconds) for males and females of 10 age groups—right hand (upper panel) and dominant hand (lower panel). The best scores within two trials of the right hand (upper panel) and dominant hand (lower panel) were used to plot the figure. Outliers were removed to easily visualize the trend of the score distribution. Data were adjusted by hand dominance for subjects of age 5 and older (lower panel).

FIGURE 3.

Box plot of the Grooved Pegboard Test times (seconds) for males and females of 10 age groups—right hand (upper panel) and dominant hand (lower panel). The best scores within two trials of the right hand (upper panel) and dominant hand (lower panel) were used to plot the figure. Data were adjusted by hand dominance for subjects age 5 and older. Subjects of age 3–9 inserted pegs in two rows, whereas subjects of age 10–85 inserted pegs into five rows (lower panel).

TABLE 1

Average and Standard Deviation of Time to Complete a Trial of the Rolyan® 9-Hole Peg Test and Grooved Pegboard Test (in Seconds)

Age (yr)	Rolyan® 9-Hole Peg Test				Grooved Pegboard			
	Right Hand		Left Hand		Right Hand		Left Hand	
	N	Mean (SD)	N	Mean (SD)	N	Mean (SD)	N	Mean (SD)
3–4	19	32.8 (6.5)	19	39.0 (7.6)	19	57.9 (16.4)	19	72.6 (20.4)
5–6	30	25.0 (3.9)	29	26.9 (4.1)	30	39.9 (11.4)	30	47.4 (16.2)
7–9	29	19.9 (3.4)	29	20.7 (2.7)	30	32.7 (13.4)	30	36.5 (14.1)
10–13	41	17.0 (2.0)	41	18.2 (2.5)	41	61.6 (11.2)	41	69.3 (19.5)
14–20	33	17.1 (2.5)	33	18.5 (2.3)	33	58.8 (6.4)	33	64.6 (8.1)
21–30	32	15.7 (1.8)	32	16.5 (1.9)	32	55.3 (7.3)	32	59.6 (8.6)
31–45	30	16.2 (2.0)	30	17.3 (2.0)	30	57.3 (8.0)	30	64.2 (12.0)
46–65	32	17.5 (2.8)	32	18.5 (2.7)	32	69.0 (18.0)	32	76.0 (16.5)
66–75	31	17.8 (2.7)	31	19.2 (3.1)	31	68.6 (17.9)	31	79.3 (16.1)
76–85	27	21.0 (2.8)	27	21.8 (2.7)	27	86.7 (16.4)	27	100.8 (24.6)
Total	304	19.3 (5.3)	303	20.8 (6.4)	305	58.7 (19.0)	305	66.6 (22.7)

N = number of subjects; SD = standard deviation.

TABLE 2

Pearson Correlations Supporting Concurrent Validity of Dexterity Measures

Measures	BOT	Purdue
9-HPT		
Right	−0.89	−0.75
Left	−0.87	−0.74
Grooved Pegboard (age 3–9)		
Right	−0.63	—
Left	−0.61	—
Grooved pegboard (age 10 and older)		
Right	−0.57	−0.73
Left	−0.50	−0.78

9-HPT = Rolyan® 9-Hole Peg Test; BOT = Bruininks-Oseretsky Test of Motor Proficiency dexterity subscale for children of ages 3–14; Purdue = Purdue Pegboard (R + L + both) subscale for ages 15 and older.

The 9-HPT correlated with BOT at −0.86 (right) and −0.83 (left) for children age 3–9 and correlated with BOT at −0.65 (right) and −0.67 (left) for children age 10 and older.