The Tyneside Pegboard Test: development, validation, and observations in unilateral cerebral palsy

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ABBREVIATIONS

9-HPT	9-Hole Peg Test
AHA	Assisting Hand Assessment
TPT	Tyneside Pegboard Test

AIM The aims of this study were twofold: first, to develop and validate a timed test of unimanual and bimanual dexterity suitable for those with disability affecting hand function; second, to explore relationships between unimanual and bimanual completion times.
METHOD We developed the Tyneside Pegboard Test (TPT), an electronically timed test with three peg sizes, incorporating an asymmetrical bimanual task. Nine hundred and seventy-four participants (455 males, 519 females; age range 4–80y) provided normative data. Test–retest reliability and construct validity were assessed (50 adults: 14 males, 36 females; 15–73y) on two occasions 2 weeks apart. Bimanual and unimanual completion times were measured in 87 children (51 males, 36 females) with unilateral cerebral palsy (CP) and 498 individuals in a comparison group (238 males, 260 females; 5–15y).
RESULTS The comparison group showed an asymmetrical U-shaped relationship between completion times and age. Intraclass correlation coefficients ranged from 0.74 to 0.91, indicating moderate test–retest reliability. There was a negative relationship between average TPT bimanual times and Purdue pegboard bimanual scores (Spearman's *rho* −0.611, degrees of freedom 44, $p<0.001$). Children with unilateral CP had greater prolongation of bimanual than unimanual completion times compared with the comparison group (mean difference 20.31s, 95% confidence interval 18.13–22.49, $p<0.001$).
INTERPRETATION The TPT is accessible for those with impaired hand function. Children with unilateral CP demonstrated disproportionate bimanual deficits, even allowing for unimanual dexterity: this has implications for therapy.

Bimanual dexterity is critical for swift, skilled performance of activities of everyday living and is impaired in conditions such as unilateral cerebral palsy (CP), with adverse consequences.[1] Development of spatial and temporal aspects of bimanual coordination[2] and constraints on these in unilateral CP[3] are well documented. However, intensive training can improve bimanual coordination,[4] and evidence based bimanual therapy interventions continue to emerge.[5] Although assessments exist for many aspects of upper limb activity in unilateral CP,[6] timed assessments of bimanual dexterity are often too challenging.[7] The Melbourne Assessment of Unimanual Hand Function and Assisting Hand Assessment (AHA) assess unimanual capacity and performance of the paretic hand in bimanual tasks respectively, but do not directly measure performance speed, a key aspect of dexterity.[6] Standard 9-hole, Annett peg-moving, Box and Blocks, and Jebsen–Taylor tests assess unimanual but not bimanual dexterity. The drawer-opening test elegantly assesses upper limb coordination but requires three-dimensional kinematics and is not primarily a clinical tool.[8]

In a comprehensive review of dexterity assessments,[7] only the Purdue Pegboard Test, Minnesota Rate of Manipulation Test, and Minnesota Manual Dexterity Test (a contemporary version of the Minnesota Rate of Manipulation Test) assessed bimanual dexterity and were adequately validated. However, Minnesota Manual Dexterity Test scores differed between two test versions.[9] The Purdue Pegboard Test was designed to assess unimanual and bimanual dexterity in those with highly skilled hand function;[10] the Grooved Pegboard Test is similarly challenging.

Manual dexterity is a key predictor of independence; it should be measured clinically and as an outcome measure in interventional trials. The 9-Hole Peg Test (9-HPT) was

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recommended for inclusion in the motor battery of the National Institutes of Health Toolbox.[11] However, clinical tests of bimanual dexterity suitable for conditions such as unilateral CP do not exist. Starting with the 9-HPT design, we aimed to develop and validate an electronically timed assessment of unimanual and bimanual dexterity accessible to those with impaired hand function.

What this paper adds

- We developed an adapted, electronically timed 9-hole pegboard test.
- Our modifications facilitate use by those with disability affecting hand function.
- The test incorporates an asymmetrical bimanual task.
- Children with unilateral cerebral palsy showed disproportionate bimanual dexterity deficits even allowing for unimanual dexterity.

METHOD

Test development and assessment protocol

The Tyneside Pegboard Test (TPT) was adapted through iterative prototype evaluations from the 9-HPT, with five main modifications, indicated in Figure 1. Participants sat with the pegboards placed on a table within comfortable reach, aligned to the midline. For each unimanual board completion, participants were instructed to pick up and transfer all nine pegs, one at a time, from one board to the other as quickly as possible, using the indicated hand only. Before the bimanual tasks, the assessor inserted the central divider. Participants were then required to pick up pegs one at a time from one board with one hand and pass them through the hole in the central divider to the other hand, which placed them in the second board as quickly as possible. For both unimanual and bimanual tasks, a demonstration and practice run occurred before the recorded board completion. Each participant performed 12 unimanual and two bimanual board completions. Test order was constant: participants first undertook four unimanual board completions with the large (most accessible) pegs, testing transfer in both directions and with each hand, dominant hand first. This was repeated using medium then small pegs, unless the participant clearly struggled to complete the boards using the previous peg size, in which case the test was terminated. Finally, bimanual dexterity was tested in both directions using the large pegs.

Participants

Normative data set

Cross-sectional data were collected from a comparison group aged 4 to 80 years, recruited through Newcastle University, public libraries, schools, and nurseries. Because around 50% of children with unilateral CP were left-hand dominant, left-handed individuals were actively sought for the comparison group. We aimed to recruit 45 individuals for the comparison group per age year from 4 to 15 years and per age decade for adults, to estimate the standard deviation (SD) for each age group within an error margin of approximately ±20% with 90% confidence.

Reliability and validity data set

To assess test–retest reliability and criterion (concurrent) validity, 50 participants (14 males, 36 females, six left-handed), aged 15 to 73 years (mean 34y, SD 13y 6mo),

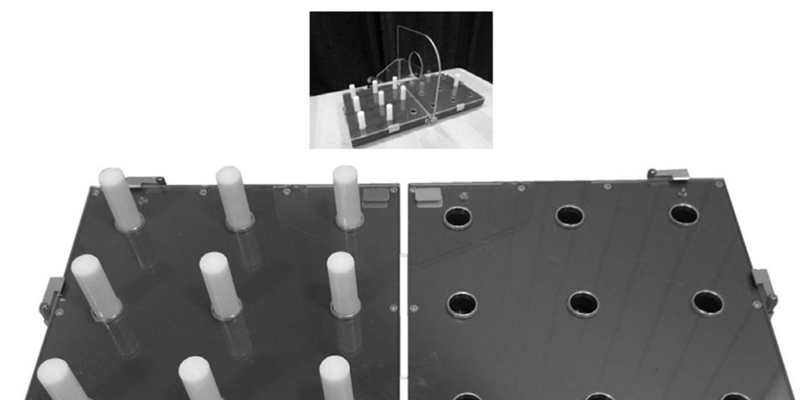

Figure 1: Tyneside Pegboard Test apparatus. The key differences from the 9-Hole Peg Test (9-HPT) are as follows. (1) Two pegboards are placed side by side, with pegs presented upright to facilitate and reduce variability of initial grasp; the task is the swift transfer of pegs from one board to the other. (2) There are three sizes of peg, starting with large pegs (shown: 58×16.5mm), progressing through medium (58×10.5mm) and small pegs (33×6.5mm, similar to the 9-HPT). Three interchangeable Perspex overlays (held in place with clips) are used, with circular aluminium inserts so each hole diameter is always 0.5mm larger than the peg diameter. (3) Interpeg distance was increased from 3.2 to 7.7cm, providing additional space to manoeuvre the hands. (4) No stopwatch is required: peg removal and replacement are electronically detected and coded through an infrared light source opposite a photovoltaic detector at the bottom of each hole, and custom written software records the timing of all peg removal and replacement events. (5) Inset: for bimanual tasks a Perspex divider with a central hole 8.5cm in diameter (lowest point of the hole 8cm above the board surface) is inserted vertically between the boards.

were invited to complete the TPT on two occasions 2 weeks apart. During the first session, participants also completed the Purdue pegboard tasks. In the bimanual Purdue task, participants place pins into holes in successive rows on a board simultaneously with both hands; the score is the number of rows completed in 30 seconds. For the Purdue assembly task, participants must make as many 'assemblies' as possible consisting of a pin and two washers with a collar in between, using both hands together, within 1 minute. The assembly task score is the total number of assembled parts.

Unilateral CP data set

Data from children aged 4 to 15 years with unilateral CP were obtained at entry into local studies of upper limb interventions. Baseline data for the AHA and (where age appropriate) the ABILHAND-Kids assessment were also available for these children.

Significant visual impairment and inability/unwillingness to participate were exclusion criteria. Additional exclusion criteria were physical disability affecting hand function (comparison group) and lack of active grasp in the paretic hand (unilateral CP). Ethical approval was obtained from Newcastle and North Tyneside 2 Research Ethics Committee and Newcastle University Ethics Committee. We obtained written informed participant/parental consent.

Data analysis

For all participants, we recorded age, sex, handedness (modified Annett questionnaire), group (unilateral CP/comparison), and completion time (in seconds) for each subtest. Unimanual completion times for the large pegs were calculated, averaged over all four conditions (two hands, two directions). Average bimanual completion time and the difference between mean unimanual (large pegs) and bimanual completion times were calculated. This difference relates to the bimanual coordination component of the bimanual task, controlling for unimanual performance with each hand.

Statistical analysis was undertaken using IBM SPSS, version 23.0 (IBM Corp, Armonk, NY, USA) and STATA (StataCorp, College Station, TX, USA) software. Participants with subsets of missing data were excluded from analyses requiring those subsets.

Normative data set

For each unimanual test in the comparison group, linear regression was performed to model the association between age (explanatory variable) and completion time (continuous outcome). Owing to the nonlinear association between completion time and age, piecewise linear regression models with three knots (age 10y, 18y, and 50y) split regressions into four connected parts. Coefficients and 95% confidence intervals (CIs) representing the change in completion time per 1-year increase in age were estimated for each age group (≤10y, 11–18y, 19–50y, and ≥51y). Models were refitted to include sex as an explanatory variable. Sex-adjusted models were compared with unadjusted models using likelihood ratio tests. Similarly, models were adjusted for hand dominance and compared with the unadjusted model. Coefficients representing change in average difference between unimanual and bimanual completion times per 1-year increase in age were estimated for each age group using piecewise linear regression with the difference as the outcome. Coefficients and 95% CIs representing completion times for large versus medium and small versus medium pegs were estimated using generalized estimating equations, with completion times for each peg size nested within-individual. Peg size ('medium' as reference category) and age (modelled piecewise) were incorporated as explanatory variables.

Reliability and validity

Bland–Altman plots examined agreement and any bias between completion times from the same participants 2 weeks apart. The mean and SD of the paired differences were calculated. Intraclass correlation coefficients (absolute agreement) were calculated using a two-way random effects analysis of variance model (ICC 2,1). The standard error of the measurement was calculated from the square root of the total mean square error term in the analysis of variance table and used to estimate the smallest real difference. For criterion (concurrent) validity, correlations between average TPT bimanual completion times and the Purdue pegboard bimanual and assembly task scores were calculated, after tests for normality and inspection of scatterplots. While TPT mean bimanual times and Purdue pegboard assembly task scores were normally distributed, Purdue pegboard bimanual times were not; therefore, Spearman's rank correlation coefficient was used. For convergent validity of the bimanual task in unilateral CP, Pearson correlations between mean TPT bimanual task times, AHA 0 to 100 logit-based scores, and ABILHAND-Kids scores were compared. As mean bimanual TPT times were positively skewed in the unilateral CP group, a reciprocal transformation was undertaken.

Evaluation of children with unilateral CP versus comparison group

To compare children with unilateral CP and the comparison group, all linear regression models were refitted to the combined data. One knot was required, splitting the regression to age less than and equal to 10 years and more than 10 years. Coefficients and 95% CIs representing between-group (unilateral CP vs comparison) differences were calculated. Generalized estimating equations were similarly refitted, adjusting for unilateral CP and age (≤10y and >10y). Interaction terms between peg size and unilateral CP were incorporated.

RESULTS

Normative data set

There were 974 comparison participants aged 4 to 80 years (455 [47%] males, 519 [53%] females; 136 [14%] left-handed). Completion time reduced significantly by approximately 1.0 second per 1-year increase in age from 4 to 10 years (Table SI, online supporting information).

Between ages 11 years and 18 years, completion time decreased by 0.1 to 0.2 seconds per year. Between ages 19 years and 50 years, completion time did not significantly alter, but from age 51 years, completion time increased by approximately 0.1 seconds per year. Including the variable sex increased the model fit in only one subtest. Including hand dominance increased the model fit for three subtests (large and medium pegs towards the non-dominant hand, and small pegs towards the dominant hand). In these models, right-handed participants completed the tests significantly quicker than left-handed people. However, the size of the difference was small (<1s) and the relatively small number of left-hand-dominant individuals in the comparison group negated the possibility of determining a reference range for this group alone. We therefore analysed the data for dominant and non-dominant hands rather than by left- or right-handedness. For all unimanual board completions, paired *t*-tests showed faster completion when moving the pegs away from the side of the hand used. The mean differences ranged from 0.22 seconds (small pegs, non-dominant hand; t=3.98, p<0.001) to 0.53 seconds (large pegs, non-dominant hand; t=10.8, p<0.001). Bimanual board completions were faster when moving pegs towards the dominant hand (mean difference 0.52s; t=7.4, p<0.001). We compared completion times (averaged across both directions) between the dominant and non-dominant hands for each peg size separately. These differences were all highly significant (t=28.5–30.0, all p<0.001), The difference in completion time between the two hands, expressed as a percentage of the summed times for each hand to correct for age-related differences in overall completion times, was remarkably consistent across the age spectrum and for all peg sizes at around 5%.

Reliability and validity

Test–retest reliability

One female right-handed participant had incomplete bimanual data and was excluded. Apart from faster completion times for some board completions on retesting, Bland–Altman plots showed no other bias (e.g. Fig. S1 [online supporting information], bimanual task). Table SII (online supporting information) shows the mean differences in completion times. Intraclass coefficients ranged from 0.81 to 0.90. The smallest real difference ranged from 1.47 to 2.48 seconds (unimanual tasks) and 2.75 to 2.95 seconds (bimanual tasks) (Table SIII, online supporting information).

Criterion (concurrent) validity, bimanual task

Data were available from 46 participants. Scatterplots showed a strong negative linear relationship between TPT mean bimanual time and Purdue pegboard bimanual score, and a weak negative linear relationship with the Purdue assembly task score (Fig. 2a,b). Correlation between TPT

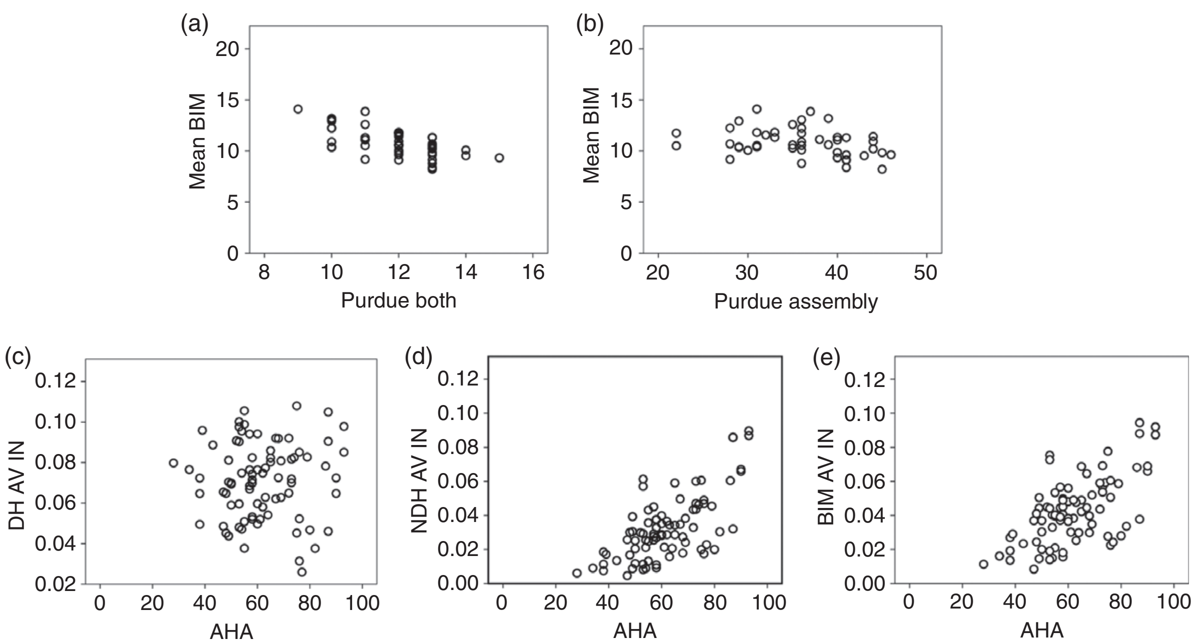

Figure 2: Scatterplots illustrating the relationship between the Tyneside Pegboard Test (TPT), Purdue pegboard bimanual tasks, and Assisting Hand Assessment (AHA) test scores. Top: scatterplots showing the relationship between Tyneside pegboard and Purdue pegboard bimanual tests. (a) Purdue bimanual task versus mean bimanual completion times. (b) Purdue assembly task versus mean bimanual completion times. Bottom: relationship between TPT and 0 to 100 logit-based AHA scores. (c) AHA versus inverted mean unimanual dominant hand completion times. (d) AHA versus inverted mean unimanual non-dominant hand completion times. (e) AHA versus inverted mean bimanual completion times. BIM, bimanual; DH, dominant hand; AV, average; IN, inverted; NDH, non-dominant hand.

mean bimanual time and Purdue bimanual score was −0.611 (p<0.001); correlation between TPT mean bimanual time and Purdue assembly task score was −0.357 (p=0.015); z-score for the difference between coefficients was −1.85.

Completion rates and convergent validity in unilateral CP

Eighty-seven children with unilateral CP, aged 4 to 15 years (58% male, 42% female; 39% right-sided unilateral CP), provided data. Of these, 81 (93%) completed all large peg tests, 76 (87%) completed all medium peg tests, 65 (74%) completed all small peg tests, and 77 (88%) completed all bimanual tasks. The mean logit-based 0 to 100 AHA score in unilateral CP was 62.0 (SD 14.3). Of the 10 children not completing both bimanual tasks, five had AHA 38 or lower, one had an AHA of 47, one 4-year-old (AHA 58) did not comply, and three had AHA scores of 53 but incomplete performance. Only one child with an AHA score under 38 (actual score 34) completed the bimanual task successfully, but with markedly prolonged completion times (88.4s and 173.7s).

AHA scores were strongly correlated with transformed (inverted) mean bimanual completion times (Pearson's r=0.63, p<0.001), and with inverted mean unimanual non-dominant hand completion times (r=0.69, p<0.001), but not with inverted mean unimanual dominant hand completion times (r=0.025, p=0.824) (Fig. 2c–e). For the 65 children aged 6 years and over, ABILHAND-Kids scores were strongly correlated with inverted mean bimanual and unimanual (non-dominant hand) completion times (r=0.65, p<0.001 and r=0.62, p<0.001 respectively), and moderately correlated with inverted mean unimanual dominant hand completion time (r=0.49, p<0.001).

Evaluation of children with unilateral CP versus comparison group

Completion times in children with unilateral CP versus comparison group

Data from 87 children with unilateral CP aged 4 to 15 years were evaluated against those from 498 in the comparison group. Fifty-eight per cent of the unilateral CP group versus 47% of those in the comparison group were male (χ^2 test, p=0.062). There were more left-hand-dominant participants in the unilateral CP group (39% vs 19%; χ^2 test, p<0.001). Children with unilateral CP had significantly longer completion times than those in the comparison group for all unimanual board completions. These differences were more marked for the non-dominant hand (Table I). They also had significantly longer bimanual completion times (towards dominant hand: mean difference 23.6s, 95% CI 20.3–26.8, p<0.001; away from dominant hand: mean difference 45.6s, 95% CI 40.9–50.3, p<0.001).

Association between peg size and completion times

For the comparison group, completion was significantly faster with the large than with the medium pegs. Completion times were also significantly faster for the medium than for small pegs in all but one subtest. For children with unilateral CP, differences between large and medium

Table I: Association between unimanual test completion times and peg size

	Coefficient (s)[a] (95% CI) p value			
Hand used	Dominant hand		Non-dominant hand	
Direction	Towards dominant hand	Away from dominant hand	Towards non-dominant hand	Away from non-dominant hand
All in the comparison group				
Large vs medium	−0.57 (−0.67 to −0.47) <0.001	−0.47 (−0.57 to −0.37) <0.001	−0.59 (−0.70 to −0.48) <0.001	−0.61 (−0.72 to −0.49) <0.001
Small vs medium	0.35 (0.25–0.46) <0.001	0.28 (0.18–0.38) <0.001	0.03 (−0.09–0.14) 0.637	0.32 (0.20–0.43) <0.001
Children with unilateral CP and those in the comparison group aged 5–15y				
Large vs medium	−0.49 (−0.86 to −0.12) 0.009	−0.65 (−1.05 to −0.24) 0.002	−0.72 (−2.37 to 0.94) 0.396	−0.69 (−2.28 to 0.90) 0.393
Small vs medium	0.29 (−0.08 to 0.66) 0.126	0.48 (0.08–0.88) 0.020	0.00 (−1.66 to 1.66) 0.999	0.39 (−1.20 to 1.98) 0.630
Group (unilateral CP vs comparison)	3.50 (2.58–4.42) 0.001	2.84 (1.90–3.79) 0.001	34.85 (30.91–38.8) 0.001	37.35 (33.12–41.59) 0.001
Interaction: large vs medium and group[b]	−2.93 (−3.92 to −1.94) 0.001	−1.64 (−2.71 to −0.56) 0.003	−9.02 (−13.45 to −4.60) 0.001	−5.93 (−10.18 to −1.68) 0.006
Interaction: small vs medium and group[c]	0.34 (−0.66 to 1.33) 0.508	0.26 (−0.82 to 1.34) 0.637	9.93 (5.26–14.59) 0.001	12.34 (7.95–16.73) 0.001

[a]Adjusted for age, modelled piecewise. Size of coefficients indicates average difference in completion times (s) for the comparison. Negative coefficients: faster completion times (seen for large vs medium pegs); positive coefficients: slower completion times (seen for small vs medium pegs). [b]Interpreted as the additional difference between large and medium test times in unilateral cerebral palsy (CP) compared with the comparison group. [c]Additional difference between small and medium test times, in unilateral CP compared with the comparison group.

peg completion times were greater than for the comparison group and were largest for the non-dominant hand; differences between medium and small peg completion times were also significantly greater, but only for the non-dominant hand (Table I, bottom two rows).

Bimanual minus unimanual (large pegs) completion times

Mean unimanual (large pegs) and mean bimanual test times were available for 883 individuals in the comparison group (90%). Figure 3 shows the age-related changes in mean bimanual and mean unimanual times (large pegs). The difference between mean unimanual and bimanual completion times decreased markedly with increasing age between 4 years and 10 years (−2.19s per year, 95% CI −2.38 to −2, $p<0.001$) and to a smaller extent between 10 years and 18 years (−0.29s per year, 95% CI −0.4 to −0.18, $p<0.001$). Between 18 years and 50 years the difference did not alter significantly (0.03s per year, 95% CI 0–0.07, $p=0.067$) but between 50 years and 80 years there was a small but significant increase in difference (0.1s per year, 95% CI 0.04–0.16, $p=0.002$). Incorporating sex and hand dominance (separately) did not improve model fit (likelihood ratio test: $p=0.368$ and $p=0.869$ respectively).

Mean unimanual (large pegs) and bimanual completion times were available for 80 participants with unilateral CP (92%). They had longer bimanual completion times than the comparison group and a larger difference between average unimanual and bimanual completion times (20.31s, 95% CI 18.13–22.49, $p<0.001$). Incorporating sex and hand dominance (separately) did not improve model fit (likelihood ratio test: $p=0.671$ and $p=0.064$ respectively). No child with unilateral CP had negative average bimanual minus average unimanual task times, compared with 4% of those in the comparison group aged 4 to 10 years and 27% aged 11 to 15 years.

For children with unilateral CP, Pearson's correlation coefficient between the total bimanual completion time and the total unimanual completion time for the non-dominant hand (0.99, $p<0.001$) was far higher than for the dominant hand (0.42, $p<0.001$). This was in contrast to children in the comparison group, for whom the coefficients were 0.88 ($p<0.001$) and 0.87 ($p<0.001$) respectively.

DISCUSSION

We have developed an electronically timed dexterity assessment incorporating an asymmetrical bimanual task, accessible to those with disability affecting hand function and applicable in a clinical setting.

Normative data set

The relationship of unimanual completion times with age was as expected.[11] The bimanual task was disproportionately slow at the extremes of age, even accounting for unimanual performance. Mature bimanual coordination involves a distributed bilateral network which is not simply the sum of each 'unimanual' network.[12] A key factor in the development of bimanual coordination is maturation of the corpus callosum;[13] furthermore, decline in callosal size and integrity with advancing age is associated with deteriorating bimanual function.[14] Transcranial magnetic stimulation

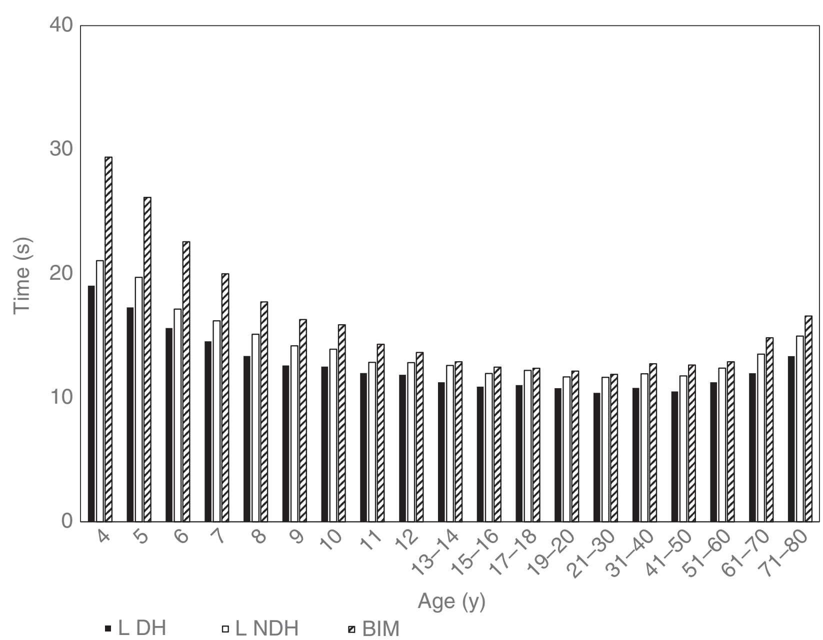

Figure 3: Tyneside Pegboard Test age-related means. Black bars, unimanual total completion time (dominant hand); unfilled bars, unimanual total completion time (non-dominant hand); hatched bars, bimanual total completion times. L, large pegs; DH, dominant hand; NDH, non-dominant hand; BIM, bimanual.

studies indicate maturation during childhood of transcallosal inhibition of electromyographic activity in hand muscles.[15] This may suppress mirror movements, which interfere when performing asymmetrical bimanual tasks. Mirror movements occur in young children and wane through adolescence,[16] reflecting the superior performance of young children in mirrored versus parallel or asymmetrical bimanual tasks. Cognitive factors may also contribute to increased bimanual completion times in young children.

Reliability and validity

The similarity of the unimanual component to existing assessments of dexterity means that face, content, and construct validity were essentially established. The novel, bimanual task was compared with the Purdue Pegboard Test as a criterion standard for those with unimpaired hand function. Correlation with the Purdue bimanual task was higher than with the assembly task, which involves a more complex sequence of object manipulation.[17]

Test–retest reliability in participants with unimpaired hand function showed mixed results, with some subtests showing improvement at 2 weeks. This issue is observed with other timed tests.[18] The largest change was in the bimanual task, suggesting a learning effect which deserves further exploration. If using the test to assess improvement with an intervention, having two baseline assessments is advisable. The TPT bimanual task was strongly correlated with both the AHA and the ABILHAND-Kids scores. The high correlation between the AHA and non-dominant hand TPT scores was expected, as the AHA assesses performance of the affected hand in bimanual tasks. The AHA was not correlated with TPT dominant hand completion times, in contrast to the ABILHAND-Kids score; this reflects the content of the ABILHAND-Kids questionnaire, which covers bimanual and unimanual tasks.

Evaluation of children with unilateral CP versus comparison group

For children aged 4 years and over with unilateral CP, an AHA score of 39 or above, ability to grasp and release, and ability and willingness to engage were associated with successful bimanual task completion.

The expected differences between unimanual performance in the unilateral CP and comparison groups were observed. Completion times with the non-dominant hand in unilateral CP were prolonged. Children with unilateral CP also showed greater effects of peg size on completion times than the comparison group. We confirmed previous findings of impairment of the 'unaffected' hand in childhood unilateral CP,[19] also seen in adults after stroke.[20] These deficits remain under-recognized and have implications for clinicians, in terms of monitoring function of the less affected hand particularly if using constraint therapy.[21]

Bimanual task and non-dominant hand completion times were strongly correlated in children with unilateral CP. Children with unilateral CP also showed a larger difference between average bimanual and average unimanual task times than the comparison group, indicating additional bimanual coordination difficulties after correcting for unimanual task components. The reasons are probably multifactorial, including pathological mirror movements, disruption to networks involved in bimanual control,[22] impairments in cognition and executive function,[23] increased visual monitoring of the affected hand,[24] lack of practice due to avoidance of bimanual tasks,[1] and the (often adaptive) apparent deterioration in performance of the less affected hand in bimanual compared with unimanual tasks.[3] Although we did not investigate this directly, the literature indicates that younger children[25] and children with unilateral CP[8] adopt a sequential approach to bimanual movements.

Strengths and weaknesses

The TPT fills a gap in the current portfolio of tests available for those with impaired hand function. The test allows comparison of unimanual and bimanual function as well as an understanding of the effect of peg size on performance: thus, while adaptations can easily be made for specific research purposes, the complete test profile is informative in a clinical setting.

A few limitations of the study must be mentioned. With cross-sectional data, associations between completion time and age may be influenced by variation between participants or cohort effects. Additionally, many factors influence bimanual task performance; future studies should capture cognitive, sensory, and visual data and quantify mirror movements to explore this further. Nonetheless, information provided by the TPT will facilitate targeting and monitoring of unimanual and bimanual dexterity during therapy. The assessment lends itself to the study of hand function in other conditions such as developmental coordination disorder, autism spectrum disorder, stroke, and Parkinsonism, and has potential for investigating motor learning. Further investigation of psychometric properties of the TPT in the paediatric and unilateral CP populations is merited.

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had no interests which may be perceived as posing a conflict or bias.

SUPPORTING INFORMATION

The following additional material may be found online:

Figure S1: Bland–Altman plots for the pegboard bimanual task.

Table SI: Association between completion times and age in the comparison group, estimated using piecewise linear regression.

Table SII: Mean differences in completion times from baseline (t_1) to retest (t_2).

Table SIII: Intraclass correlation coefficients, standard errors of measurement, and smallest real differences.

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