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# THE HAND FUNCTION OF CHILDREN WITH AND WITHOUT NEUROLOGICAL MOTOR DISORDERS

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## Introduction

This study focuses on the development of a hand function evaluation model to identify children's hand functional demands. The hand function of a human being emerges at the preschool age when the physical aspects of the hand gradually develop (Erhardt, 1982). A young child integrates the physical components of the hand into the various hand functional skills in response to environmental and socio-cultural needs (Henderson and Pehoski, 1995). Therefore it is rather important to study how hand function develops and adapts to daily demands. An accurate assessment would allow a therapist to plan and provide appropriate intervention, as well as to evaluate progress, with the ultimate goal of achieving an evidence-based practice within the therapy profession (Exner, 1990). This study was therefore undertaken to help medical professionals and therapists to formulate a conceptual model for evaluating children with hand dysfunction based on the study of normal hand development in childhood. The research study also focuses on the study of the measurements of performance components using standardised assessment methods and on how this performance will affect the functional performance in coping with activities of daily living (ADL) and school related activities (work/leisure).

## Objectives of the study

The main objectives of this research are:

1. To develop and validate a hand function evaluation model for pre-school children from 4 to 6 years of age.
2. To study how neurological disorders may affect the hand function performance of children.

### *Children with Neurological Motor Disorders*

Children with neurological motor disorders constitute a large percentage of the clients of an occupational therapy practice (Gordon, *et al.*, 1996). A variety of conditions exist in which the neurological system is impaired, interfering with the

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child's ability to interact effectively with the environment (Exner, 1990). Cerebral palsy (CP), one of the neurological motor disorders, is defined as a disorder of movement and posture that is caused by a nonprogressive brain lesion that occurs in utero, during or shortly after birth and is expressed in variable impairments in the coordination of muscle action and sensation (Bobath, 1980; Colangelo and Gorga, 1996). Several classifications of cerebral palsy have been developed according to the quality of tone, disorder distribution, and locale of brain lesion. Common conditions that include mild, moderate and severe spasticity indicate lesions in the motor cortex. The variability of the movement and postural disorder may be classified according to which limbs are affected. Involvement of one extremity is commonly referred to as monoplegia, upper and lower extremities on one side as hemiplegia and lower extremities as paraplegia. If all four extremities are involved, then it is termed quadriplegia. When a child with quadriplegia has mild upper limb involvement and more significant involvement of lower limb function, then it is called diplegia (Bobath, 1980). This research has chosen the hemiplegic group of subjects for study mainly to control the variability of the disease which has direct effect on the hand function and to gain deeper understanding of one particular client group. Hand function problems of this group of children are often associated with problems of motor control, sensibility and sensory processing and persistence of primitive grasp reflex. Past studies indicated that simple hand splinting can facilitate hand function of children with CP (Exner and Bonder, 1983; Goodman and Bazyk, 1991; McPherson, 1981). Improvements were shown in the active range of motion, grip strength, cube stacking and Box and Blocks test. Studies on treatment efficacy require valid and reliable assessment tools to ensure the effectiveness of a programme. Most of the past studies did not address hand function in coping with daily activities such as writing. Comparing the sensorimotor performance in terms of grip and active range of motion may not reflect the actual functional demands of a child in coping with his self care demands and the academic demands of school (Barrett and Jones, 1967; Case-Smith, 1995). Therefore, in the evaluation of the hand function of this group of children, other than measurement of the sensorimotor performance, the hand function tasks should be assessed and analysed. Special movement patterns should be noted and analysed in a qualitative manner instead of quantitative measurement.

### *The Hand Function Evaluation Model (HFEM)*

The Hand Function Evaluation Model (HFEM) (Figure 1) was developed based on Haley's model on the Motor Assessment Outcome model (Haley, 1992), ICIDH (the International Classification of Impairments, Disabilities and Handicaps) (WHO, 1980), Nagi's model of health status (Nagi, 1991) and on the ICF (International Classification of Function and Disablement) (WHO, 2001).

#### *Level I*

In the new model, Level I represents the intrinsic factors that a child possesses. The basic components include development of sensorimotor performance, visual perceptual skills, cognitive functions and psychosocial aspects of development. Deficits in these areas result in sensorimotor, visual perceptual, cognitive or

psychosocial dysfunction. Assessments are often conducted specifically to assess the deficits or impairment resulting from congenital, trauma or other problems. Assessment at this level is often needed in the acute onset of injuries, indications of surgical or other medical interventions, pre- and post- operation comparison and evaluation of treatment. In this study, the focus is on the sensorimotor performance of children with cerebral palsy.

***Level II***

At this level, a child is viewed globally with respect to developmental progression. Standardised developmental assessments are used to ascertain those children with fine motor delays. Most of these developmental assessments are criterion referenced or norm referenced. Children are often asked to conduct a series of task items, which are related to their age. Assessment at this level can help facilitate referrals for appropriate therapy or placements, planning of teaching and learning programmes in a preschool setting. Parents and caregivers often rely on developmental assessment results to plan for their children's future and to provide suitable home intervention where necessary. The Peabody Developmental Motor Scales-Fine Motor (PDMS-FM) has been chosen for this study because its validity and reliability has been demonstrated by previous research (Stokes, *et al.*, 1990; Gebard, *et al.*, 1994; Russell, *et al.*, 1994; Boulton, *et al.*, 1995). A Chinese version of the test battery has been standardised and validated (Tsang, 1999).

***Level III***

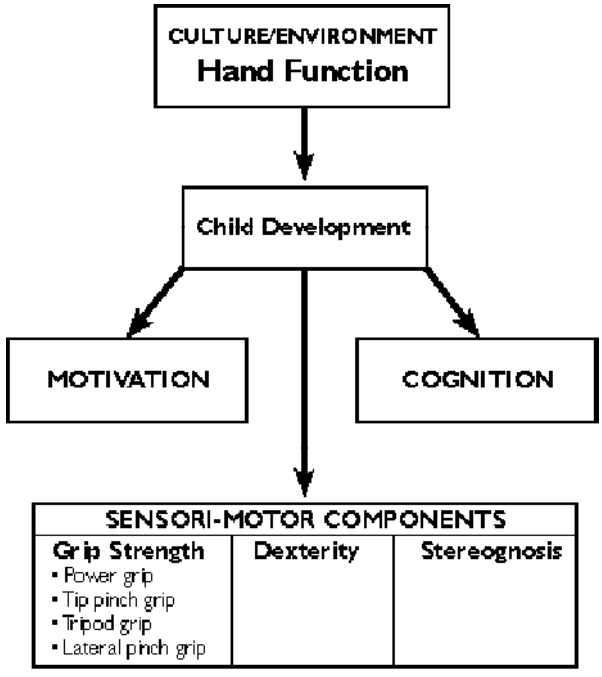
In this model, the hand function outcome is defined as "the abilities of the hand to cope with purposeful everyday activities including self care and academic skills" (Henderson and Pehoski, 1995). Children at this level are expected to conduct goal oriented or purposeful hand function activities. Both unilateral and bilateral activities essential for pre-academic and self-care demands are equally important in defining the hand function of a child. Four hand function outcome measures; namely writing, chopsticks (unilateral hand function), buttoning (button up/unbutton) and scissors tasks (bilateral) are proposed to be the outcome indicators relevant to the Hong Kong preschool children (Tsang, 1999). Writing and scissors cutting activities are essential for pre-academic activities whereas the chopsticks manipulation and the buttoning tasks are essential for daily self-care demands. The hierarchical position is buttoning, writing, chopsticks and scissors skills. Standardised methods of assessments in these four functional measures were developed and reliability and validity of these methods were studied (Tsang, 1999).

## Methodology

### *Research design*

This is a cross sectional study comparing the hand function of children with and without neurological motor disorders. The study is based on the hand function evaluation model (Tsang, 1999) and the assessment protocol is also developed at the three levels of hand function performance (Figure 1). Four kindergartens were selected randomly from the four regions of Hong Kong (HK) (namely Kowloon, Hong Kong, NT East and NT West) based on the list of kindergartens registered at The Education Department of HK. In each

**FIGURE 1**
**The conceptual model of the Hand Function Evaluation Model (1999)**




kindergarten, 15 boys and 15 girls were selected from three grades of study namely K1 (foundation), K2 (intermediate) and K3 (senior) classes using the stratified sampling method. 120 children were thus selected to participate in the study after consent from their parents was obtained. Sixteen children with hemiplegia, a type of cerebral palsy, were selected from the outpatient clinics in one of the regional hospitals by using a convenient sampling method. The inclusion and exclusion criteria are described below.

### *Sampling method*

*Selection of normal subjects (Group A)*

Children between 4 and 6 years of age without previous upper limb injuries. Medical conditions remain normal as reported by kindergarten teachers. Children with the following conditions were excluded from the study:

1. previous injuries on upper limbs, recent operation;
2. other medical problems including auditory, visual problems or epilepsy;
3. unstable medical conditions; and
4. severe behavioural problems in class.

*Selection of subjects with neurological motor disorders (Group B)*

*Inclusion criteria*

1. Subjects must be diagnosed with hand dysfunction resulting from cerebral palsy with hemiplegia having limited hand function

2. No cognitive deficits and highly motivated to join the study
3. Between 4 and 6 years of age.
4. Stable medical conditions.

*Exclusion criteria*

1. children with cognitive or perceptual deficit;
2. children with epilepsy;
3. children with severe spasticity of upper limbs
4. children with poor sitting balance; and
5. children with emotional and behavioural problems

## *Instrumentation*

Based on the hand function evaluation model (FIGURE 1), the following three levels of assessments were developed:

*Sensorimotor performance (Level I):*

1. Power grip: the force generated by flexing all four fingers with thumb in opposition on the Jamar dynamometer.
2. Tip pinch grip: the force generated by using the tip of thumb and tip of index finger to press on the Dexter pinch gauge.
3. Three point chuck grip (tripod grip): the force generated by the tip of thumb, tip of index finger and middle finger by pressing on the Dexter pinch gauge
4. Lateral pinch grip: the force generated by the thumb and the lateral side of index finger when pressing on the Dexter pinch gauge.
5. Stereognosis: The ability to discriminate between objects without vision. In this study, it is operationally defined as the ability to discriminate between 10 common objects from a bag without visual cues.
6. Dexterity: the ability to make skillful manipulative movements with small objects, using primarily the fingers. In this study, it was measured by asking a child to move 20 twenty cents coins from one box to another with standardised test procedures.

*Developmental fine motor skills (Level II):*

In this study, the Peabody Developmental Motor Scale (Fine Motor) was used to measure the developmental progression of fine motor skills relative to the child's age. The Chinese version of the PDMS-FM scale was developed and validated in a previous study. The test-retest reliability and inter-rater reliability was found satisfactory with ICC values ranging between 0.89-0.95 (Tsang, 1999)

*Hand function performance (Level III):*

It is defined as the abilities of the hand to perform functional tasks related to ADL and academic demands. In this study, this was operationally defined as the abilities to write, to button, to use chopsticks and to use scissors for cutting. The four hand function performances were Chinese handwriting skills, chopstick manipulation skills, buttoning skills and scissors skills. Instruments to measure these four skills were the Chinese handwriting test, Chopsticks manipulation test, buttoning test and scissors test which were developed and standardised locally. The reliability of these subtests was tested in a previous study (Tsang, 1999).

*Statistical analysis*

The independent T-test was used to compare the mean differences between the normal subject group (Group A) and the disabled subject group (Group B) on each subtest with the level of significance set at 0.05. Demographic data was presented using mean and standard deviation.

## Results

A total of 120 children were selected from the four kindergartens and sixteen children from the outpatient clinic for the study. Among the normal subject group (Group A), there-were 60 boys and 60 girls with a mean age of 63.7 months. For the disabled subject group (Group B), there were altogether 10 boys and 6 girls with a mean age of 65.3 months. The mean age difference between the two groups was not significant. There were 31.2% left-handers in group B and only 7.5% in Group A.

*Sensorimotor performance*

Children with neurological motor disorders demonstrated greater grip strength in pinch grip ($t=-3.14$, $df=131$, $p=0.00$) and lateral pinch grip ($t=-3.87$, $df=131$, $p=0.00$) of the dominant hand. However, when comparing the affected (non-dominant) hand with the normal children group, they scored poorly on power grip ($t=4.15$, $df=131$, $p=0.00$), pinch grip ($t=4.83$, $df=131$, $p=0.00$), lateral pinch grip ($t=3.24$, $df=131$, $p=0.00$) and tripod grip ($t=5.33$, $df=131$, $p=0.00$).

Subjects in Group B showed no significant difference in the stereognosis test ($t=0.06$, $df=131$, $p=0.96$) of the dominant hand but had a very poor score compared to the normal children group of the non-dominant hand ($t=-3.41$, $df=131$, $p=0.00$). In terms of dexterity, children with neurological motor disorders showed poor results for both the dominant ($t=-2.95$, $df=131$, $p=0.01$) and non-dominant ($t=-4.98$, $df=131$, $p=0.00$) hand.

*Developmental fine motor skills*

Children with neurological motor disorders ($t=3.90$, $df=15.15$, $p=0.00$) were found to have significant delay in fine motor skills as compared to the subjects in Group A. It was found that among the four categories of hand skills, the bilateral skills and the co-ordination skills were affected most.

*Hand functional skills*

Children of Group B also had problems with bilateral functional tasks in scissors skills ($t=-2.79$, $df=16.58$, $p=0.01$) and buttoning ($t=-5.06$, $df=16.97$, $p=0.00$) but demonstrated no problems in writing ($t=-0.67$, $df=16.88$, $p=0.51$). They were also weak in chopstick manipulation skills ($t=-3.04$, $df=16.79$, $p=0.01$) compared to the normal subjects.

## Discussion

Altogether 120 normal children were selected making up Group A and 16 children with neurological motor disorders were selected forming Group B. Demographic data showed that the mean age of the two groups were similar ($p>0.01$). All the sixteen children with neurological

**TABLE I**
**Comparison of grip strength measurements between normal (Group A) and children with neurological motor disorders (Group B)**

| Group | | | Mean | (S.D.) | *t-value* | *df* | p-value |
|---|---|---|---|---|---|---|---|
| Power grip | Dominant | A | 15.91 | (4.48) | 0.00 | 131 | 0.99 |
| | | B | 15.91 | (3.73) | | | |
| | Non-dominant | A | 14.12 | (4.39) | 4.15 | 131 | 0.00** |
| | | B | 8.92 | (4.84) | | | |
| Pinch grip | Dominant | A | 4.48 | (1.35) | -3.14 | 131 | 0.00** |
| | | B | 5.77 | (2.14) | | | |
| | Non-dominant | A | 4.14 | (1.23) | 4.83 | 131 | 0.00* |
| | | B | 2.39 | (1.64) | | | |
| Lateral Pinch grip | Dominant | A | 6.16 | (1.41) | -3.87 | 131 | 0.00*** |
| | | B | 7.53 | (2.40) | | | |
| | Non-dominant | A | 5.43 | (1.51) | 3.24 | 131 | 0.00** |
| | | B | 3.87 | (2.84) | | | |
| Tripod | Dominant | A | 5.83 | (1.63) | -1.95 | 131 | 0.05* |
| | | B | 6.81 | (2.75) | | | |
| | Non-dominant | A | 5.31 | (1.33) | 5.33 | 131 | 0.00** |
| | | B | 3.14 | (2.23) | | | |

Note: p<0.05* p<0.01** p<0.001***

**TABLE II**
**Comparison of stereognosis and dexterity between normal children (Group A) and children with neurological motor disorders (Group B)**

| | | Mean | (S.D.) | *t-value* | *df* | p-value |
|---|---|---|---|---|---|---|
| Stereognosis | | | | | | |
| Dominant | Group A | 83.14 | (32.85) | 0.06 | 131 | 0.96 |
| | Group B | 82.43 | (50.36) | | | |
| Non-dominant | Group A | 92.99 | (41.13) | -3.41 | 131 | 0.00** |
| | Group B | 137.61 | (50.01) | | | |
| Dexterity | | | | | | |
| Dominant | Group A | 37.21 | (13.22) | -2.95 | 131 | 0.01*** |
| | Group B | 73.70 | (49.20) | | | |
| Non-dominant | Group A | 41.44 | (18.18) | -4.98 | 131 | 0.00*** |
| | Group B | 114.83 | (58.53) | | | |

Note: p<0.05* p<0.01** p<0.001***

**TABLE III**
**Comparison of PDMS-FM scores between normal children (Group A) and children with neurological motor disorders (Group B)**

| PDMS-FM Scores vs Group | Mean | (S.D.) | *t-value* | *df* | p-value |
|---|---|---|---|---|---|
| Normal group | 218.18 | (5.06) | | | |
| Disabled group | 192.50 | (26.28) | 3.90 | 15.15 | 0.000* |

**TABLE IV**
**Comparison of hand function performance between normal children (Group A) and children with neurological motor disorders (Group B)**

| Hand f(x) vs Group | | Mean | (S.D.) | *t-value* | *df* | p-value |
|---|---|---|---|---|---|---|
| Writing | A | 849.95 | (257.51) | -0.67 | 16.88 | 0.51 |
| | B | 897.03 | (331.00) | | | |
| Chopsticks | A | 58.71 | (35.92) | -3.04 | 16.79 | 0.01** |
| | B | 102.81 | (56.34) | | | |
| Scissors | A | 430.98 | (175.66) | -2.79 | 16.58 | 0.01* |
| | B | 634.98 | (286.1) | | | |
| Buttoning | A | 60.29 | (19.69) | -5.06 | 16.97 | 0.00** |
| | B | 97.99 | (29.56) | | | |

motor disorders attended normal or integrated kindergartens and received weekly treatment at the outpatient clinics in the local hospitals.

The hand function evaluation of Group B clearly illustrated differences in sensorimotor performance between the dominant (unaffected) and the non-dominant (affected) hand. There were differences in grip strength and stereognosis test scores between children with and without neurological dysfunction. Children with hemiplegia (Group B) had similar grip strength to that of the children in Group A in the unaffected hand but decreased grip strength in the affected hand. This showed that they might have good motor function of the hand in terms of grip strength in the unaffected hand. They also scored poorer than the children in Group A in the dexterity test. This might be explained by the fact that the hand function is controlled by the cortical spinal tract and that although only one side of the body is affected, there might be a cortical lesion thus affecting the dexterity and co-ordination of the "unaffected" hand (Henderson, 1995)

The results of the stereognosis test were comparable with regard to the unaffected hand but relatively poor for the affected hand. Dexterity scores for both hands were much lower than those of the normal subjects showing that children of Group B had clumsy hand movements of both hands despite the unilateral involvement. Poor sensory feedback and the lack of controlled movements of the hand might attribute this problem of dexterity to the "affected" hand.

There was a significant delay ($t$-value=3.9, $df$=15.5, p= 0.001) in the developmental fine motor skills among children with hemiplegia. Some test items

**FIGURE 2**
**A child with hemiplegia picking up a small object with wrist inflexion.**

assessing the coordination skills of children require bilateral hand movements which children with hemiplegia had difficulty to perform. Moreover, since the dexterity of the "unaffected" hand was also poor, it affected the overall performance. This can be explained by the fact that the cortical spinal tracts of children with hemiplegia are affected, thus resulting in problems in fine motor skills. This delay in fine motor skills development could be remedied by providing early developmental training.

In terms of hand function measures, children in Group B had few problems with writing using the unaffected hand. Yet, they scored poorly in buttoning (*t*-value=-5.06, *df*=116.97, p= 0.00) and scissors skills (*t*-value=2.79, *df*=16.58, p= 0.01). It was found that their chopstick manipulation skills were significantly lower than normal despite the fact that most of the children had unilateral involvement (*t*-value=-3.04, *df*=16.79, p= 0.01). This further substantiates the view that although there are differences between the affected hand and non-affected hand, neurological deficits may be present in the "unaffected" hand. Therefore, therapists should focus training on bilateral hand function rather than just on the affected hand. It is also clear that through repetition and refinement of prehension, even a child with neurological deficits can also master functional hand skills like writing.

From a qualitative observation, the problems of dexterity and manipulation became conspicuous by the inappropriate stabilisation of wrist and forearm due to neurological deficits among this group of children. A normal child could easily pick up a small object with wrist stabilised in extension. However, the hemiplegic child had difficulty in stabilising the wrist in extension so as to allow the hand to grasp or pinch. This obviously slows down the process of reach, grasp and release (Figure 2).

## Implication for practice

This study has adopted the hand function evaluation model to evaluate the hand function performance of preschool children. Results indicated that the hand function performance of children could be reflected in three levels of performance, namely sensorimotor performance, developmental and function performance. Children with deficits at different levels could be evaluated objectively and systematically. In this way, therapists could obtain a comprehensive background of a child's hand function performance. Thus, intervention at different levels could be planned and developed. The evaluation model may also serve as evidence for an effective intervention programme in hand function training for children with dysfunction.

## Limitations of the study

The samples selected in Group B (subjects with hemiplegic cerebral palsy) are relatively small due to the difficulties in finding subjects within the inclusion criteria. There is an unequal group comparison between the children with and without neurological motor disorders. Therefore, this study could not be generalised to all children with neurological motor disorders. It could not be generalised to other types of conditions because there will be more confounding factors for children with multiple handicaps and more severe involvement. Another limitation of this study is that the number of subjects selected from the four kindergartens may not permit generalisation to the whole population of preschool children due to the limited sample size. Further studies with larger samples could better represent the normative hand function performance of preschool children in Hong Kong.

## Summary

This study aimed to establish a hand function evaluation protocol to compare the hand function abilities of children with and without neurological motor disorders. One hundred and twenty preschool children between 4 to 6 years of age participated in being assessed on sensorimotor function, developmental fine motor skills and hand functional tasks. The same evaluation was repeated on sixteen children of similar age with the neurological disorder of hemiplegia. Results indicated that there were differences in grip strength ($p=0.01$), sensibility ($p=0.00$) and dexterity ($p=0.00$), developmental fine motor skills ($p=0.001$), chopsticks manipulation ($p=0.01$), buttoning (fasten/unfasten buttons) ($p=0.04$) and scissors skills ($p=0.00$) between the two groups of children. Children with hemiplegia also demonstrated weaker precision grip ($p=0.00$) and dexterity ($p=0.01$) on the unaffected hand. It was concluded that children with hemiplegia were poor in the overall hand function performance although only one side of the body was affected. They had poor dexterity skills of the "unaffected" hand. The research is significant for alerting therapists to focus on training of sensorimotor, developmental and functional hand tasks for children with this neurological disorder.

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