Neonatal Brachial Plexus Palsy: the role of diminished sensibility of the hand on functional recovery

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CHAPTER 2

Hand Sensibility in Healthy Young Children

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ABSTRACT

Objective

The aims of the study were (1) to assess hand sensibility in healthy young children using instruments validated for adults; (2) to identify which test tools are suitable; and (3) to compare the dominant and non-dominant sides.

Patients and Methods

Twenty-five healthy children aged 7-11 years (mean 9.5 years) were investigated. Sensibility was assessed with the Semmes-Weinstein Monofilament test (SW), two-point discrimination (2PD), localization test (LOC) and stereognosis object recognition (SOR). Sensory stimuli were administered to fingertips.

Results

The thinnest SW filament (D; 2.83mm) was felt at 94% of examined points. A 2PD at the smallest distance of 2 mm was found in the thumb in 84% of children and in the index finger in 94%. Only 60% felt this distance in the fifth digit. The difference between little finger and index finger was statistically significant ($p = 0.001$). Near-maximum value on the LOC was scored in both hands. All children had a 100% score for both hands in the SOR.

Conclusions

Most children can detect touch in the digits at low pressure. The majority are able to discern two points 2 mm apart in the first and second digits, but significantly less so in the fifth digit. Children are well able to localize on which side of a fingertip pressure is applied. Objects are recognized very well, and occasionally too quickly to record. There appear to be no differences between the dominant and non-dominant hands in either test. Adjustment of sensory test protocols routinely used in adults is necessary to optimize hand sensation testing in children, in view of the detection limits.

INTRODUCTION

Hand sensation provides crucial feedback information to the central nervous system, regarding aspects like pressure to adjust grip in specific tasks, or pain to warn against danger. Hand function is affected when sensory feedback is disturbed due to disorders of the central or peripheral nervous system. The most serious situation is that of a 'blind hand', where visual control is needed to compensate for the absence of sufficient sensory input.[1]

It is not clear why, so far, little effort has been made to objectify hand sensation in children, whereas it is known that sensory deficits have a negative impact on their functioning as adults. Moreover, normal afferent input is of eminent importance for the correct development of the brain, and disturbances may lead to 'developmental apraxia'.[2] This lack of instruments hampers objective evaluation of the sensory status of the hand, frustrating proper interpretation of its function. In addition, it means that efficacy of treatment is difficult to evaluate.
It was recently published only about 10% of all axons in a mixed peripheral nerve are efferent (motor) fibers and that the majority of fibers are afferent (sensory).[3] These afferent fibers are seldom evaluated as outcome parameter after recovery of nerve lesions, resulting either spontaneous recovery or from nerve reconstruction. Especially in NBPP, the literature on sensory outcome is scarce, compared to results of motor outcome.

Tests to obtain objective information regarding specific qualities of hand sensation in adults have been validated.[4] These tests are also used in children, but it is not well established whether these tests provide equally useful information and, therefore, whether they should be applied in children. The need for a reliable test method to evaluate hand sensation in children has become relevant in view of developments in peripheral nerve reconstructive surgery, especially for severe neonatal brachial plexus palsy (NBPP), peripheral nerve lesions and cerebral palsy. Sensory testing in adults with NBPP who were conservatively treated showed abnormalities in the outcomes of the Semmes-Weinstein monofilament test, two-point discrimination, object recognition and a locognosia test.[5] Children with severe NBPP are surgically treated and the focus of outcome evaluations so far has been on motor function recovery. Much less emphasis has been put on sensory function recovery. It remains to be established how sensation affects functional outcome and can be optimized.

There is therefore a need for objective evaluation outcome measures to compare results of specific surgical repairs and hand therapy support, in order to optimize treatment strategies. The current literature does not provide clear information on ways to evaluate sensory function in children and the best tests to use.

Monofilaments exerting different pressures have been used before to detect touch in children. One study of 43 children aged between 6 and 12 years applied monofilaments to the shoulder (C5), index finger (C6), thigh (L3) and external malleolus (S1). The results were compared with data from the literature regarding adults. The analysis showed that children and adults obtained similar sensory scores. Sex, age and laterality did not have a significant effect on the findings. The index finger proved to be the most sensitive site to test.[6]

Two-point discrimination (2PD) can be used in children aged 7 years and older; its reliability is decreased in younger children.[7] The tip of the index finger was found to be more sensitive in children, compared with the thenar eminence of the hand and the external malleolus of the foot.[8]

The primary aim of the current study was to establish values for hand sensation in healthy young children using test methods validated for adults. The secondary aim was to identify which assessment tool might be suitable to diagnose diminished sensibility in clinical practice. The third and final aim was to assess whether differences in sensibility exist between the dominant and non-dominant hands in healthy children.

PATIENTS AND METHODS

Participants

Twenty-five healthy children aged 7-11 years (mean 9.5 years), without any history of disease or trauma potentially effecting sensation or cognition, participated in this study. The children were recruited at the Montessori school in Voorburg, The Netherlands. The study was announced on the school's message board. The school provides regular Dutch standard level education. The minimum age was set at 7 years, as from this age up children are able to take part in threshold testing.[7] Additionally, this is the age at which blind or visually impaired children start training for tactile writing systems (like Braille), and hand dominance becomes clear.[9]

The study protocol was approved by the Medical Ethics Committee of Leiden University Medical Center (ABR nr. 48977) and informed consent was given by the parents.

Sensory Testing

The sensibility of both hands was assessed using four different methods: (1) Semmes-Weinstein Monofilament test (SW); (2) two-point discrimination (2PD); (3) localization test (LT) and (4) stereognosis object recognition (SOR).

Modifications were made to suit the smaller size of the children's hands and their ability to understand and remain concentrated. These modifications were tested first in a pilot involving a number of healthy children, before the actual study was performed. A screen was positioned such that it prevented the children from seeing the hand being tested. Sensory stimuli were given on the palmar side of the fingertips. The hand was categorized as dominant if it was their writing hand. Both hands were studied with all test methods, in the same order. Each method was used first on the dominant hand. Each test started with a demonstration and a short practice period.

Semmes-Weinstein Monofilament Test (SW)

Monofilaments of three different diameters (D 2.83 mm; F 3.61 mm; J 4.31 mm) were applied two times, with a 1.5 second interval, for each fingertip, going from the thumb to the little finger. Each filament was vertically positioned on the fingertip and pressed until it bended, for 1 second. Thus, the pressure applied to the fingertip corresponded to the diameter of the filament.[10] The thinnest filament, D, was used first, followed by the filaments with a larger diameter. The SW test was scored positive if at least one of the two stimuli per finger for each monofilament was felt. Once a filament had been felt, thicker filaments were no longer applied.

Two-point discrimination (2PD)

The McKinnon-Dellon Disk-Criminator® was used for 2PD testing. The Disk-Criminator® consists of a plastic frame with on its outer rim pairs of metal dots and one single dot. The distances between the paired dots range between 2 mm and 6 mm. The weight of the instrument was placed on the fingertip with the two points in the longitudinal direction of the finger in order to ensure equal pressure each time. The tips of the thumb, index finger and small finger were statically tested in both hands. The children were asked to indicate whether they felt one dot or two dots as varying dot distances were applied in both descending order (from 6 mm to 2 mm) and ascending order (2 mm to 6 mm) as described previously.[11] The order varied for each finger. A score was considered positive if the child correctly discriminated two points five consecutive times. The smallest distance between the dots that could be discriminated was documented as the best score.

Localization test (LT)

The test protocol described by C. Jerosch-Herold et al. was used.[12] The thickest SW monofilament was pressed for 2 seconds on the radial or ulnar half of the fingertip. The children were asked to indicate in which part of the hand they felt the pressure. A drawing of the hand with numbered regions of the fingertips was shown to them during the test to help them describe the localization. (Figure 1)

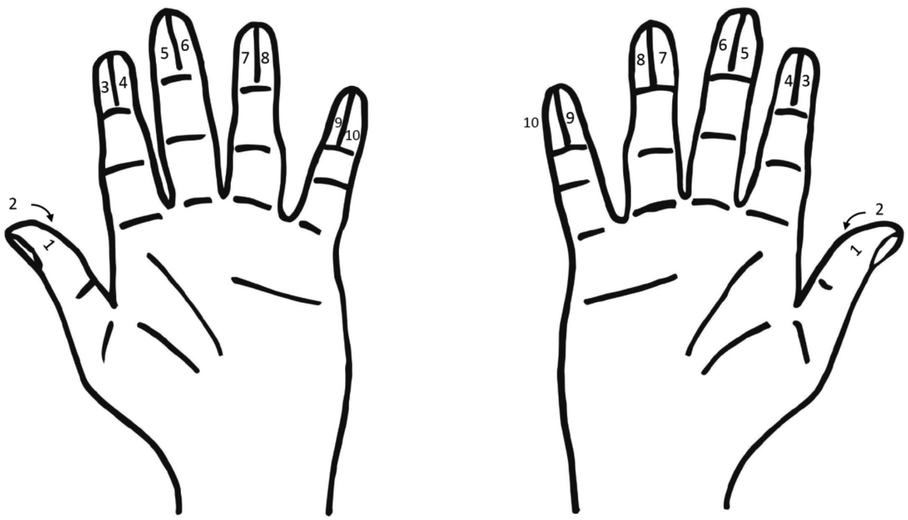

Figure 1 Localization areas on fingers

Each region that was correctly identified scored two points. One point was scored if the pressure was localized either in the correct half but on an adjacent finger, or in the wrong half of the correct finger. The individual scores were added to form a sum score. Thus, the maximum score that could be attained per hand was 40. For each finger, both halves were scored and a maximum of two points was given; two test rounds were performed (5x2x2x2).

Stereognosis: object recognition (SOR)

Both hands were put behind a screen.[13] Six small objects (eraser, small paper ball, Lego brick, bead, coin, button) were successively placed between the fingertips, in alternating sequence, starting with the dominant hand. The child had to identify the object. A similar series of objects remained in sight in front of the screen to facilitate recognition.

Statistical analysis

Paired t-tests for continuous variables and McNemar tests for categorical/dichotomous variables were employed. Data were analyzed with SPSS Statistics for Windows, version 22 (IBM Corporation, Armonk, NY, USA).

RESULTS

A total of 50 hands were analyzed. One of the 25 children was left-handed.
After the analysis of the first 25 children, an interim-analysis showed that the findings in these children were very similar. For this reason, recruitment of a larger group was judged not necessary.
The standard deviations of the results in all three tests were relatively small, therefore, we concluded that testing more children to obtain a larger group size would not lead to other conclusions. (Table 1).

Table 1 Comparison of dominant versus non-dominant hand in three tests (25 pairs).

	Mean score (St.Dev)		Paired sample t-test		
Test	**Dominant hand**	**Non-dominant hand**	**Difference of means**	**Confidence Interval (95%)**	**Significance (2-tailed)**
SW	4.56(1.26)	4.68(1.14)	-0.12(0.12)	(-0.37 - 0.13)	0.33
2PD	2.20(0.27)	2.23(0.34)	-0.03(0.06)	(-0.15 - 0.10)	0.66
LT	36.20(3.57)	37.24(3.60)	-1.04(0.55)	(-2.18 - 0.10)	0.07

Legend Table 1

Mean scores on SW, 2PD and localization tests, for each hand, dominant versus non-dominant, and results of the paired-sample t-test.

Semmes-Weinstein Monofilament

The thinnest filament (D 2.83) was felt 235 times (94%) and the second thinnest (F3.61) was felt the remaining 15 times (6%). The thickest filament (J.4.31) thus did not need to be used for testing. For statistical analysis, a score of 1 was noted when the thinnest filament (D 2.83) was felt, and a score of 0 when the second thinnest filament (F3.61) was felt. We compared pairs of fingers, grouped by hand dominance, to assess whether one of the fingers was more sensitive than the other. In 88-92% of cases, the same (thinnest) monofilament was felt in both fingers. (Table 2) The average sum score for all fingers was 4.56 for the dominant hand and 4.68 for the non-dominant hand. (Table 1) We found no significant difference between the fingers of either the dominant or the non-dominant hand.

Table 2 Results of SW testing.

Side		**DD**	**FF**	**FD/DF**	**p***
dominant	dig 1 vs dig 5	88%	4%	8%	0.5
	dig 1 vs dig 2	88%	8%	4%	1.0
	dig 5 vs dig 2	92%	4%	4%	1.0
non-dominant	dig 1 vs dig 5	92%	4%	4%	1.0
	dig 1 vs dig 2	92%	8%	0%	1.0
	dig 5 vs dig 2	92%	4%	4%	1.0

Legend Table 2

DD: both fingers felt the D (thinner) filament;
FF: both fingers felt the F (thicker) filament;
FD/DF: combination of thick/thin or thin/thick;
*: p-value from Mc.Nemar test.

Two Point Discrimination

The average 2PD for thumb, index finger and little finger was 2.20 mm for the dominant hand and 2.23 mm for the non-dominant hand. On the thumb (digit 1), the children were able to detect two points with a 2 mm distance in 84% of cases. For the index finger this was 94%, but for the small finger only 60%. The difference between little finger and either the thumb or the index finger was statistically significant. (Table 3) It was found that 5 and 6 mm testing was useless, and only took up precious time.

Table 3 Comparison of two-point-discrimination in pairs.

Side		Mean 2PD* (mm)	p**
dominant	dig 1 vs dig 5	-0.160	0.161
	dig 2 vs dig 5	-0.320	0.003
non-dominant	dig 1 vs dig 5	-0.360	0.001
	dig 2 vs dig 5	-0.400	0.001

Legend Table 3
* mean difference between pairs;
** p-value from 2-tailed paired-samples t-test.

Localization test

An almost maximum score was achieved in both hands. The average for the right hand was 36.2 and for the left 37.2. Scores did not differ significantly between the fingers. (Table 4)

Table 4 Localization test, comparison between different pairs of fingers.

Side		Mean*	p**
dominant	dig 1 vs dig 5	-0.36	0.19
	dig 1 vs dig 2	0.08	0.80
	dig 2 vs dig 5	-0.44	0.16
non-dominant	dig 1 vs dig 5	-0.12	0.50
	dig 1 vs dig 2	0.00	1.00
	dig 2 vs dig 5	-0.12	0.45

Legend Table 4
* mean difference in score between pairs;
** p-value from 2-tailed paired-samples t-test.

Stereognosis test

All children had 100% scores for both hands. The objects were recognized very rapidly with each hand, making it impossible to measure the time taken to recognize a single object. The time taken to identify all objects in both hands was 64 seconds.

DISCUSSION

The primary aim of the current study was to determine normal values of hand sensation in healthy young children by applying sensibility test methods validated for adults. We found that only light pressure with an SW filament (D; 2.83mm) was needed for the stimulus to be detected in 94% of the examined points on the fingertips. The best ability to distinguish two adjacent points was found for the index finger, closely followed by the thumb, but it was significantly less in the little finger. Both in the dominant and non-dominant hands, localization scores were close to the maximum. Scores for object recognition were 100% for both the dominant and non-dominant hands. Overall, we observed no significant difference between the dominant and non-dominant hands in any of the four tests.

Previous studies have found that the index finger (C6) is the most sensitive site on the human body to detect touch, more so than the shoulder (C5), upper leg (L3) or lateral ankle (S1).[4] Obviously, this ability is useful since objects, textures and pinch are felt predominantly with the thumb and index finger.

Menier found a mean 2PD of 2.2 mm for the index finger in children aged between 6 and 13 years, which is similar to our results.[8] A previous study found that the 2PD threshold was lower in 5-year-old children than in children aged 11.[14] We did not include such very young children in our study, but more recent studies did not confirm this finding.[6,8] Minor differences between those aged 6 and 13 years have been reported, but without statistical significance. One explanation might be the small sample size (n = 11) in one of these studies.[8] The sample size in our own investigation was too small to enable a definite conclusion on a relationship between age and 2PD. A decrease in threshold values has been shown to occur in adults with increasing age from 20 years up in a large population of 427 subjects.[11]

The secondary aim of our study was to identify which test tools might be suitable to diagnose a diminished sensibility among children in clinical practice. The thinnest SW filaments (D 2.83) and a 2PD distance of 2 mm on the index finger were detected by the majority of the children. We conclude that these two tests should actually be made more sensitive for the pediatric population. This would require including a monofilament with a diameter smaller than 2.83 mm, and a 2PD test with a distance between two dots of less than 2 mm. The value of the current tests for children with a peripheral nerve lesion, for instance NBPP needs to be assessed. The scores found in the present study may imply that it is important to use a more precise measurement tool allowing the exact measurable distance in mm to be read. Simply using a bent paper clip is insufficient.

The little finger appeared to be less sensitive than the thumb and index finger. This might indicate that the density of sensory receptors in the tip of the index finger is higher than in the other fingertips. This is relevant if superior trunk or median nerve lesions have to be identified by comparing sensation with that of an area innervated by an intact inferior trunk or ulnar nerve.

We observed that the localization test required a lot of concentration of the children. Some of the youngest children had to be actively encouraged to complete the test. The reason might be the large number of points that were examined. Interestingly, many of the children asked if they were allowed to quickly move their fingers in between stimuli. They commented that they could feel better when they moved their digits. It appears that active finger movement is required for optimal conditions to localize a stimulus.

The stereognosis test as we performed it proved to be of no value in assessing sensibility. The objects were too easily recognized. Children were able to name the object immediately after it was put between their fingertips. It was not even necessary for them to flex their fingers around the object. As a result, the time recording mainly recorded how quick the examiner was at putting the objects on the children’s fingertips. In view of these results, we feel that although this test might be valuable in showing gross pathology, it will not help to discriminate subtle sensory differences.

The third and final aim was to assess whether differences in sensibility exist between the dominant and non-dominant hands. We did not find any significant differences with the tests we applied, which is important if either the dominant or non-dominant hand is involved in a condition affecting sensation.

Validated measurement tools for sensibility in children are lacking. We adapted and tested a set of four methods routinely used in adults. Future research should determine the need to develop specific tests for children, taking into account children's understanding, concentration span and the smaller size of their fingers.

CONCLUSIONS

Testing hand sensation in children by applying the tests routinely used in adults provides useful information, but has limitations as well. Optimizing the detection of diminished sensation requires adaptation by compensating for intrinsic differences in sensation and concentration span related to the young age.

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