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Original Article

Deficits in Elbow Position Sense in Neonatal Brachial Plexus Palsy

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ABSTRACT

BACKGROUND: In neonatal brachial plexus palsy, sensory recovery is thought to exceed motor recovery with little attention paid to long-term assessment of proprioceptive ability. However, there is growing evidence that reduced somatosensory function frequently accompanies motor deficits as a result of activity-dependent changes in the central nervous system. Given the importance of proprioception in everyday motor activities, this study was designed to investigate position sense about the elbow joint in neonatal brachial plexus palsy. **METHODS:** A convenience sample of seven individuals with neonatal brachial plexus palsy aged 9-17 years and in seven control individuals aged 10-16 years were recruited for the study. An elbow position matching task was used in which passive displacement of the forearm (reference arm) was reproduced with the same or opposite arm. In both conditions, matching was performed in the absence of vision and required utilization of position-related proprioceptive feedback. **RESULTS:** Position-matching errors were significantly greater for the affected versus the unaffected arm when reproducing a reference position with the same arm. When matching was performed using the opposite arm, errors were dependent upon which arm served as the reference arm. When the unaffected arm served as the reference position, affected arm matching errors were not significantly different from control values. However, in the reverse situation, in which the unaffected arm relied on reference feedback from the affected arm, matching errors doubled compared with control values. **CONCLUSIONS:** These results provide evidence that position sense is impaired in neonatal brachial plexus palsy and illustrate the importance of assessing proprioception in this population.

Keywords: brachial plexus palsy, proprioception, somatosensory, upper limb

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Introduction

Neonatal brachial plexus palsy (NBPP) results from injury to the nerves of the brachial plexus and affects approximately 1.5 of 1000 live births.[1] In children with NBPP, paresis or paralysis of the upper extremity presents as the defining deficit, most often affecting elbow flexion and shoulder abduction and external rotation. In addition to strength-related limitations affecting activities of daily living,[2] kinematic analysis of arm-reaching activities has revealed altered movement patterns including greater scapular upward rotation[3] and increased elbow flexion at the beginning of movement,[4] suggestive of impaired multijoint control occurring at the central nervous system level.[3]

Reflective of the traditional clinical focus of regaining movement, most research centered on functional changes in NBPP has addressed the assessment and recovery of motor ability in this population, partly because of the view that sensory recovery is thought to typically exceed motor recovery.[2,5] However, some children who regain control of particular muscle groups do not recruit these muscles during self-initiated activities. Further, a reduction in motor activity is accompanied by decreased movement-related sensory feedback that, in turn, can lead to cortical reorganization of sensorimotor brain areas underlying coordinated, goal-oriented motor behavior. This phenomenon has been demonstrated in both animal and human models following cerebral insult[6,7] or in peripheral

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deafferentation[8] where a reduction in movement is associated with reorganization of corresponding sensorimotor cortices. Functionally, somatosensory deficits have been described in adult stroke[9] and cerebral palsy[10,11] conditions that manifest primarily as motor system impairments.

Because proprioceptive information is critical for the learning and execution of efficient and well-coordinated movements, it is important to understand whether peripheral nervous system injury leads to deficits in the use of sensory feedback that, in turn, may further compromise motor function. Consequently, the purpose of this study was to examine position sense about the elbow joint in older children and adolescents using a well-established limb position matching paradigm.[10,12]

Materials and Methods

Participants

A convenience sample of seven individuals with unilateral NBPP (9.7-17.0 years, mean age: 12.0 years) participated in this study. None had undergone nerve reconstruction or secondary reconstructive surgery, nor were any receiving physical or occupational therapy at the time of testing. A right-handed control group (10.1-15.7 years, mean age 12.6 years) was also tested for comparison purposes. All participants had normal cognitive function and attended public schools. In the NBPP group, mean active elbow flexion-extension range of motion was 138-25°. Muscle strength was sufficient to lift the affected arm against gravity. In all cases, the unaffected hand was the dominant hand. All procedures were approved by the University of Michigan Medical School Institutional Review Board. Written consent was obtained from the participants' parents and assent was obtained from the participant before the onset of testing.

Testing procedures

Grip strength was assessed using standard clinical dynamometry techniques and tactile spatial acuity was measured using a grating orientation task.[13] Functional ability was assessed using the nine-hole peg test. Elbow position matching ability was tested using a method employed previously to study upper limb proprioceptive acuity across the lifespan[12] and in pathological conditions affecting arm function.[10,14] Participants were seated and blindfolded with their forearms resting on top of two height-adjusted, frictionless levers that pivoted beneath the elbow joint in the horizontal plane. The forearm was pronated with the hands lightly grasping a handle located at the distal end of the lever. If grip ability was insufficient to maintain hand position throughout the testing session, the hand was secured to the handle with foam underwrap tape. Shoulder position was approximately 70° of abduction and 15° of flexion.

The position-matching task involved a 20° elbow extension movement (110° start position) to a passively generated reference target position (Fig 1). In the ipsilateral remembered task, the forearm was passively displaced to the reference position, held at that position for 3 seconds, and returned to the start position. The participant was then given a verbal cue to "match" the reference position with the same arm using only memory-based proprioceptive information. In the contralateral concurrent task, the forearm was displaced and held in the reference position while matching was performed with the contralateral arm. In this condition, proprioceptive feedback was available throughout the matching task but required interhemispheric transfer of position-related information.

For both tasks, matching was performed with the unaffected/dominant arm and with the affected/nondominant arm. Task and arm order was randomized with five trials recorded for each task/arm combination. Change in elbow joint displacement was recorded as the voltage output of precision potentiometers mounted beneath the pivot point of each lever. The analog signal was digitized at 100 Hz, filtered (fourth-order

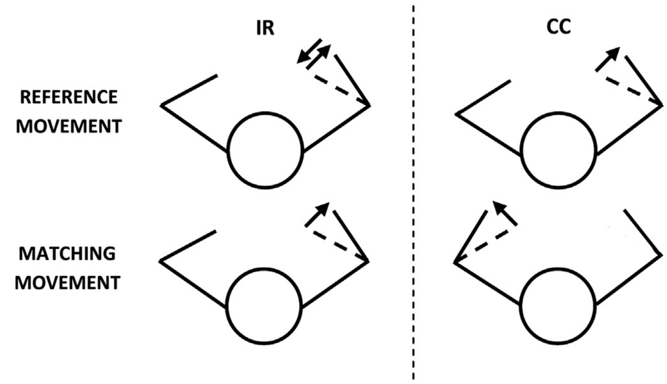

FIGURE 1.
Schematic showing elbow position matching task from an overhead perspective. Reference movement refers to generation of the target reference position; matching movement refers to the actual matching of the reference position by the participant. Dashed lines indicate elbow start position; arrows indicate direction of forearm displacement. CC = Contralateral concurrent; IR = Ipsilateral remembered.

Butterworth, zero phase lag), and multiplied by a displacement calibration coefficient prior to data analysis. Measures of matching accuracy included absolute error (error between the reference position and the actual position) and constant error. Constant error, defined as the signed difference between the target and actual positions, was used to give an indicator of average accuracy across trials as well as any directional bias with positive values indicative of overshooting the target and negative values indicative of undershooting. Movement amplitudes were calculated from the differentiated displacement data using a threshold-detection algorithm of ±2 standard deviations from baseline (0°/sec velocity) to determine movement onsets and offsets. Tests for statistical significance ($P < 0.05$) were performed using the mixed model procedure (SPSS 18) with Sidak corrections.

Results

Functional measures are shown in the Table. In the NBPP group, clinical tests of motor and sensory function showed significant declines in the affected hand (mean maximum grip strength: $P = 0.03$, mean index finger tactile spatial acuity threshold: $P = 0.02$). Hand dexterity, assessed using the nine-hole peg test was poorer on the affected side although differences were not statistically significant because of high variability in affected hand scores.

Memory-based proprioceptive errors were approximately 40% greater when matching was performed with the affected compared to the unaffected arm in the NBPP group ($P < 0.01$) (Fig 2A). In contrast, errors associated with unaffected arm matching did not differ significantly from control group errors. Position matching deficits were also seen in the contralateral concurrent matching task requiring interhemispheric transfer of proprioceptive

TABLE.
Mean (±1 SD) scores for tactile spatial acuity, grip strength, and manual dexterity (nine-hole peg test)

	Tactile Spatial Acuity (mm)	Grip Strength (kg)	Nine-Hole Peg Test (sec)
Unaffected	0.8 ± 0.4	22.5 ± 7.2	15.2 ± 1.9
Affected	1.9 ± 1.0	13.5 ± 6.5	19.2 ± 7.3