Assessing Midline Crossing Ability in Adults With Spastic Diplegic Cerebral Palsy

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The purpose of this study was to determine if adults with spastic diplegic cerebral palsy (CP) display midline crossing inhibition (MCI) in the lower extremity as measured by choice reaction time (CRT) and movement time (MT) as compared to participants without disabilities. Midline crossing ability was assessed in the standing position using a protocol developed by Eason and Surburg (1993). Both groups were significantly slower in the contralateral direction as compared to the ipsilateral and midline direction as measured by CRT. Results revealed that adults with CP were significantly slower in CRT and MT tasks as compared to participants without disabilities. Assessment of midline crossing ability may provide useful information related to assessment and subsequent treatment as individuals with CP age.

Individuals with Cerebral Palsy (CP) present a broad range of static nonprogressive motor disabilities acquired before, at, or within five years of birth as a result of a defect or lesion to the immature central nervous system. This condition results in the impairment of muscle coordination along with a reduced capacity to maintain posture and balance and to perform typical movements and skills (Davis, 1997; Dzienkowski, Smith, Dillow, & Yucha, 1996; Fernandez, Pitetti, & Betzen, 1990; Turk, Overeynder, & Janicki, 1995). Depending on the location and amount of damage to the brain, symptoms may vary. These symptoms range from mild manifestations including generalized clumsiness or a slight limp to severe manifestations dominated by abnormal reflexes and the inability to ambulate (Dabney, Lipton, & Miller, 1997; Styer-Acevado, 1994). With more severe cases, sensorimotor integration, proprioception, vestibular input, and visual input are altered (Dzienkowski et al., 1996; Fernandez et al., 1990). While the lesion is in itself nonprogressive, the manifestations change as the nervous system matures (Jahnsen, Villien, Egeland, Stanghelle, & Holm, 2004; Strauss, Ojdana, Shavelle, & Rosenbloom, 2004; Turk et al., 1995). The aging process may actually increase the degree of neurological problems as a person becomes more dependent upon the integrity of the nervous system.

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Pediatricians often use motor milestones to screen infant motor development. By using a multistep screening process, delay in attainment of these motor milestones is part of a diagnosis used to identify a child with CP (Allen & Alexander, 1997). Cross lateral integration is a motor milestone that appears around year eight or nine (Cermak, Quintero, & Cohen, 1980; Schofield, 1976; Stilwell, 1981). Attainment of cross lateral integration has been explained in the context of body scheme development, spatial orientation enhancement, and bilateral coordination (Ayers, 1971; Goody & Rheinholdt, 1952; Kephart, 1971; Schilder, 1950). The inability to achieve this milestone is called cross lateral or midline crossing inhibition (MCI). Cross lateral integration is referred to as the ability to execute a motor action that results in looking, reaching, or stepping across the body’s midline. Crossing the body involves the ability to move a body part, such as the leg, comfortably to the contralateral side of the body. Ayres (1976) indicated that children with sensory integration dysfunction often manifest a reluctance, rather than an inability, to cross the body’s midline. A technique for measuring MCI is predicated upon the information processing paradigm (Eason & Surburg, 1993). The premise of this technique states that crossing the midline is a more complex task than ipsilateral movements, and increased task complexity results in a longer processing time. A traditional index for information processing is reaction time; this was used to assess MCI.

Researchers who have used the MCI assessment protocol show the emergence of a developmental model. Similar to the integration of primitive reflexes, midline crossing becomes integrated during the early years of development, but this may not occur in individuals with certain types of disabilities. The inability to cross the midline of the body has been found with both the upper and lower extremities in populations that are developmentally delayed, including mental retardation (Eason & Surburg, 1993; Porretta, 1987; Surburg & Eason, 1999; Surburg, Johnston, & Eason, 1994; Woodard, Surburg, & Lewis, 1998) and learning disabilities (Woodard & Surburg, 1999). Assessment of the lower extremity was examined in two populations that experience a neurological degeneration: Huntington’s Disease (Lewis, Woodard, & Surburg, 1997) and the elderly (Lombardi, Surburg, Eklund, & Koceja, 2000).) The motor decline experienced by these populations may be manifested by the reappearance of midline crossing inhibition. By utilizing this MCI protocol and measuring choice reaction time and movement time, both cognitive and motor system processing can be examined.

Several investigators have shown that most children with CP have significant impairments of visual-perceptual abilities (Cobrink, 1959; Czudner & Rourke, 1972; Lehman, 1971). Lehman tested simple reaction time in the upper limb and determined that children with CP had much slower reaction time. Czudner and Rourke found that older children with CP ages 10 to 13 were not different from the age-matched peers on a reaction time test in the upper limb. Parks, Rose, and Dunn (1989) utilized a fractionated reaction time task for the upper limb with adolescents who had spastic CP. An increase in premotor time was found, but no difference in motor time was demonstrated in this group. McLellan and Drowatzky (1993) tested individuals 5 to 30 years of age with CP on simple and choice reaction time tasks using the upper limb. With each additional task added to make the test more complex, an increase in processing time was also found. This study found that children age 5 to 10 with CP were slower than age-matched typical participants, which is similar to the findings of Czudner and Rourke (1972).
Developmental studies of children with CP have demonstrated that children with neurological impairments achieve motor milestones at a much later chronological age than their typically developing peers (Sala & Grant, 1995). The factors contributing to this delay may include delayed maturation or dysfunction of the nervous system (Nashner, Shumway-Cook, & Marin, 1983). The presence of motor impairments may adversely interact with the aging process throughout the lifespan for persons with CP and result in atypical development (Strauss et al., 2004). In comparison to the general population, an earlier onset of motor dysfunction including mobility, strength, and endurance problems are seen (Turk et al., 1995). Although there is a plethora of research conducted on children with CP, there is a paucity of literature related to adults with CP as they age and their motor performance.

Thus, the purpose of this study was to investigate CRT and MT in adults with spastic diplegic CP and age-matched neurologically typical adults. Physical declines in adults with CP do not appear to be simply age-related but are partly the consequence of years of altered movement patterns that are compounded by the development of neuromuscular and musculoskeletal conditions. In order to determine whether differences in CRT and MT are influenced by increasing complexity as measured by activities that cross the midline, assessment of the motor milestone cross lateral integration was also examined. Motor milestones have long been a measure to screen and evaluate children with CP. Although MCI has been examined in both the upper and lower extremities, lower limb assessment may provide greater insights into motor performance and be less influenced by issues related to dexterity and handedness. A deterioration of locomotion skills has been reported as a pronounced problem in adults with CP (Jahnsen et al., 2004). This decline is seen at an earlier age than in adults without disabilities. Measuring lower limb CRT and MT performance may provide useful insight into the loss of independent function and ambulation seen in adults with CP as they age.

**Method**

**Participants**

Ten adults with spastic diplegic CP 18 to 39 years of age (see Table 1) and ten adults without neurological disabilities 20 to 39 years of age participated in this study. Both groups consisted of 7 men and 3 women. Recruitment for participants with CP was primarily through local physicians and physical therapists. Individuals with spastic CP were chosen due to the more uniform neuromotor deficits and their common neuropathologic etiology associated with prematurity (Badell-Ribera, 1985). Spastic diplegia is characterized by greater involvement of the lower extremities (Watt, Robertson, & Grace, 1989). All participants were screened prior to testing and based on self-report, were free of visual, vestibular, and hearing difficulties. Nor were they prone to seizures or taking any medication known to affect equilibrium. The primary mode of ambulation in these participants was independent walking without the use of assistive devices. All participants were also within the typical range of intellectual capabilities. Prior to the testing protocol, participants were assessed by the Ashworth Scale (Bohannon & Smith, 1987); all participants with CP had a score of 2 (more marked increase in tone throughout the ROM but affected...
parts easily moved) and participants without disabilities had no spasticity (score of 0). All participants received and signed a copy of the Human Subject Consent Form. Participants were tested in a single session. All testing procedures for MCI were administered in a university Motor Control Laboratory. Participants received financial renumeration.

**Apparatus**

Participants performed a choice reaction time (CRT) and movement time (MT) task with the lower extremity using a modification of Eason and Surburg’s (1993) MCI apparatus. The rationale for this apparatus is based upon an information processing paradigm of which the basic measurement index is reaction time. MCI was thus operationally defined as significantly slower contralateral movement when CRT and MT performance was investigated for ipsilateral, midline, and contralateral tasks with the lower extremity.

The stance used by participants is described as a modified tandem position with one foot slightly in front of the other (heel lined up with toe) and the feet approximately 5 inches (12.7 cm) apart. The MCI apparatus was placed on the floor in order for the participant to stand on the board in the modified stance position. The apparatus consisted of a rectangular piece of plywood equipped with a microswitch touch pad and three target pads (see Figure 1). A red light emitting diode (LED) was positioned directly behind each target pad. The microswitch touch pad was situated in the bottom center of the board, while the three target pads were situated with one target pad directly in front of the microswitch touch pad, one to the right and one to the left of the microswitch touch pad. All three target pads

<table>
<thead>
<tr>
<th>Participant</th>
<th>Mean age</th>
<th>Gender</th>
<th>Ashworth score</th>
<th>Preferred limb</th>
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<tbody>
<tr>
<td>1</td>
<td>33</td>
<td>M</td>
<td>2</td>
<td>right</td>
</tr>
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<td>9</td>
<td>31</td>
<td>F</td>
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<tr>
<td>10</td>
<td>31</td>
<td>M</td>
<td>2</td>
<td>right</td>
</tr>
</tbody>
</table>

MEAN 28.0 ± 6.41
were an equal distance (35.6 cm) from the microswitch touch pad, with the right and left targets positioned at 45 degree angles in relation to the microswitch touch pad. The apparatus was 60 cm × 90 cm and 1.5 cm thick. The microswitch touch pad and three target pads were 8 cm in diameter and constructed out of a durable, orange rubber material mounted on a 8 cm × 10 cm rectangular metal plates. The LEDs positioned behind the target pads were also mounted in 3 cm × 2 cm metal frames and placed 7 cm behind the target pad. A yellow LED was placed 20 cm behind the middle target LED. The warning signal was housed in a 15 cm × 10 cm box. For the measurement of CRT and MT, a portable laptop computer interfaced
through a standard parallel printer port to the midline crossing inhibition apparatus. A basic computer program was written to generate the randomization for each block of trials and to record all data.

**Testing Procedure**

Trials were initiated by depressing the touch pad following the warning signal in the form of a buzzer. Participants were instructed to watch for one of the LEDs to illuminate and to then move the foot as quickly as possible from the touch pad to the target pad of the activated LED. Preparatory intervals, the period from the depression of the touch pad to the presentation of the stimulus, were 1.5, 3.0, or 4.5 seconds in duration. The sequence of movement directions, catch trials, and preparatory intervals were based upon a stratified random procedure that insured an equal number of different preparatory intervals, catch trials, and target stimuli usage. The interval between the LED illumination and release of the touch pad constituted choice reaction time. By depressing the target pad, participants completed the task. The elapsed time from the release of the touch pad (CRT) until depression of the target pad constituted movement time (MT). A testing session consisted of 30 trials: nine midline movements, nine ipsilateral movements, and nine contralateral movements presented in a random stratified order. Three catch trials were administered throughout a testing session. During a catch trial, the warning signal (yellow LED) was given but the stimulus was not presented; therefore, no movement was to occur. The purpose of a catch trial was to prevent anticipation by participants. To ensure central location of the limb, participants were comfortably standing on the midline crossing apparatus behind the touch pad with the patella on the side being tested, positioned directly behind the touch pad. Before testing began, lower limb preference was determined by a series of activities, including standing on one foot for 5 seconds, kicking a ball from a stable position, and walking up a set of stairs. By convention, the preferred limb is the limb acting on and manipulating an object, whereas the non-preferred limb is used as a stabilizing support (Beling, Wolfe, Allen, & Boyle, 1998). Both legs were tested during a block of trials, but the order of testing was randomized between legs. Before the initial testing protocol, all participants completed five trials as orientation in which they were familiarized with the testing equipment and procedures. The average duration of a testing session was approximately thirty minutes.

**Data Analysis**

Intraclass correlation coefficients were calculated for the two dependent variables (CRT and MT) in the MCI protocol in order to assess reliability. Pearson Product Moment correlations were computed to determine the relationship between CRT and MT. Data were analyzed by a multivariate analysis of variance (MANOVA). The appropriate $F$ values associated with Hotelling’s Trace was the statistical test of choice. When significant $F$ values were found for the independent variables of interest, separate analysis of variance (ANOVA) was used to determine significant main effects and interactions on the dependent variables. Because of the repeated variables present in this design, corrected $F$ ratios were calculated based on the work of Greenhouse and Geisser (1959) that assumes the presence of maximal
heterogeneity. Independent variables for the midline crossing task were as follows: group (participants with CP and participants without CP), gender (male and female), lower limb (preferred and nonpreferred), and movement direction (movement in the contralateral, ipsilateral, or midline direction). Dependent variables related to midline crossing inhibition assessment consisted of CRT and MT. Tests of simple main effects were used to analyze significant interactions. Tukey’s test of pairwise comparisons was used for additional post hoc analyses. Effect sizes (ES) were calculated for significant results. Significance was set at $p < .05$ for all statistical comparisons.

**Results**

In reference to the reaction time protocol, intraclass correlation coefficients were calculated to determine the reliability of CRT and MT scores across trials for each group (see Table 2). Intraclass correlation coefficients for CRT ranged in value from 0.95–0.98 for CRT for both groups of participants. The values for intraclass correlation coefficients for MT ranged in value from 0.79–0.99. Pearson Product Moment correlations were computed in order to ascertain the extent of independence between the CRT and MT scores in adult participants with CP as well as participants without CP. The Pearson Product Moment correlation coefficient for CRT and MT for participants with CP was $r = 0.30$ ($p > .05$) and for nonCP participants, the value was $r = 0.21$ ($p > .05$).

A MANOVA was conducted with CRT and MT as the dependent variables. Significant main effects for group, $F(2, 17) = 18.75, p < .001, ES = 0.69$ and movement direction, $F(4, 68) = 5.88, p < .001, ES = 0.26$ were found.

**Reaction Time**

No statistical significance was found for gender, therefore this variable was collapsed in order to increase the sample size. Significant main effects for CRT were found for group, $F(1, 18) = 24.35, p < .001, ES = 0.58$ and movement direction,

<table>
<thead>
<tr>
<th>Table 2</th>
<th>Intraclass Correlation Coefficients for CRT and MT Measured Across Trials in Adults With CP and Adults Without CP</th>
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<tbody>
<tr>
<td></td>
<td>Preferred leg</td>
</tr>
<tr>
<td>Choice Reaction Time</td>
<td></td>
</tr>
<tr>
<td>Adults with CP</td>
<td>0.97</td>
</tr>
<tr>
<td>Adults without CP</td>
<td>0.98</td>
</tr>
<tr>
<td>Movement Time</td>
<td></td>
</tr>
<tr>
<td>Adults with CP</td>
<td>0.97</td>
</tr>
<tr>
<td>Adults without CP</td>
<td>0.89</td>
</tr>
</tbody>
</table>
Midline Crossing Ability in Cerebral Palsy

\[ F(2, 36) = 11.40, \ p < .001, \ ES = 0.39. \] The means and standard deviations for CRT are illustrated in Figure 2. Tukey’s method for pairwise comparisons revealed that contralateral movements were significantly slower than ipsilateral and midline movements for both groups. All reaction times were longer (e.g., slower) in adult participants with CP than adults without CP.

**Movement Time**

The results for MT scores demonstrated no statistical significance for gender, therefore this variable was collapsed in order to increase the sample size. There was a significant main effect for group, \( F(1, 18) = 24.00, \ p < .001, \ ES = 0.57. \) Because direction was necessary in determining midline crossing inhibition, the means and standard deviations for MT are illustrated in Figure 3. Participants with CP were significantly slower than adults without CP but not in a specific direction.

**Discussion**

**Reaction Time**

The results of this study provide evidence that there is a statistical difference in overall choice reaction time between the two age-matched groups: Participants with spastic diplegic CP were slower and more variable. The results of the current study are in agreement with the findings of Parks and colleagues (1989). They reported

![Figure 2](image-url)

*Figure 2—Means and standard deviations of choice reaction time (measured in seconds) for adults with CP and adults without CP*
that in a simple reaction time task, adolescents (12 to 16-year-old participants) with CP required more time to plan a simple aiming task, as measured by fractionating reaction time in comparison to age-matched peers. There were significant differences for premotor but not motor time as well as greater variability of performance in adolescents with CP. These researchers hypothesized that adolescents with spastic CP had delayed reaction times due to central processing problems. The study conducted by Parks and colleagues focused on accuracy demands, and the results indicated that adolescents with CP had greater difficulty performing a task, as evidenced by the significant findings obtained for premotor time. There were no significant findings for motor time, which suggested that the differences were solely due to information processing delays within the central nervous system.

The two major differences between the Parks and colleagues' (1989) investigation and the current study were the use of the upper limb, as opposed to the lower limb, and the complexity of the task. The Parks and colleagues study utilized information processing as the theoretical framework, similar to the current study, in which the traditional measurement index of motor ability is reaction time (Schmidt & Lee, 1999). The current study reinforces the view that processing skills are an important factor contributing to movement difficulties experienced by adults with spastic diplegic CP.

The findings in the current investigation are inconsistent with two previous studies that examined reaction time measurements in children and adolescents with spastic CP. Czudner and Rourke (1972) continued a line of study initially explored by Lehman (1971) who found that children of various ages with CP were
significantly slower on a simple reaction time task as compared to age-matched participants involving their upper limb. Czudner and Rourke tested two age groups, children 6 to 9 and 10 to 13, and compared participants with spastic CP with age-matched peers. Results from this study were that older children with CP were not different from their age-matched peers on a simple reaction time task, whereas younger children with CP were significantly slower.

The findings in the current investigation are also inconsistent with the study conducted by McLellan and Drowatzky (1993), who investigated simple and complex tasks individuals with spastic CP and age-matched participants in the upper limb. They reported differences in children ages 5 to 10. Reaction time was comparable in individuals with CP and age-matched participants after the age of 10. Stimulus complexity seemed to affect both groups equally in the McLellan and Drowatzky study. These researchers suggested that central nervous system processing improved over time in individuals with spastic CP, which was demonstrated by a decreased reaction time and was not significantly different from age-matched peers. In the literature, developmental studies have shown that reaction time decreased from childhood to adulthood, but there was limited information regarding adults with disabilities as they age (McLellan & Drowatzky, 1993).

In the current study, 18 to 39-year-old participants with spastic diplegic CP exhibit deficits in choice reaction time involving their lower limb as compared to age and gender matched participants. The participants in the current study are older as compared to the participants in the previously discussed studies. A trend in the literature is that reaction time measures decrease as a developmentally typical population ages up to 30 years (Schmidt & Lee, 1999) before slowing over time; there is no documented evidence whether this occurs in adults with physical disabilities. The current study differs from the aforementioned investigations where the other studies measured CRT in the upper extremity. Individuals with diplegic CP are characterized by greater involvement of the lower extremities and concomitant degeneration of independent ambulation. By performing the assessment on the lower limb, an increased level of complexity may have been introduced to the assessment protocol. Reaction time tasks that are performed in a seated position have a stable base of support that may be lacking in a standing posture. Children with CP have documented postural control problems, such as inappropriate muscle organization, late onset of muscle activation, and abnormal sensory integration ability (Nashner et al., 1983). Liao, Jeng, Lai, Cheng, and Hu (1997) found that children with CP had greater body sway than age-matched peers, although this did not reach statistical significance. Lewis and Surburg (2002), however, found that values for static balance in adults with CP were significantly greater and more variable than for age-matched adults. In addition to balance difficulties related to standing posture in the lower limb, participants in the current study may have been more affected by spasticity. The earlier investigations that measured reaction time in the upper limb in children with spastic diplegic CP were not assessing the most affected body part. As all participants exhibited a score of 2 on the Ashworth scale tested at their lower limb, their muscles may have been in a contracted state before the movement was initiated thus increasing CRT measures as well.

We found a significant difference between the contralateral direction and ipsilateral reaction times for both groups. The implications are that the complexity of the task (e.g., direction) is a processing issue, which is demonstrated by increased
reaction time. CRT delays, as evidenced by a slowness when comparing contralateral to ipsilateral movements (MCI), are identified in individuals with neurological processing issues, including children with learning disabilities (Woodard & Surburg, 1999) and adolescents and adults with mental retardation (Eason & Surburg, 1993; Porretta, 1987; Surburg et al., 1994; Woodard et al., 1998). In comparison, age-matched adolescents and adults with typically developing cognitive abilities have not displayed midline crossing deficits. Lewis and colleagues (1997) investigated adults with neurodegenerative Huntington’s Disease, who were 24–55 years of age. These adults exhibited an inhibition to cross the midline in the lower extremity. It was hypothesized that adults with spastic diplegic CP would also demonstrate a reluctance to cross the midline of the body, especially as this population, in general, achieves motor milestones at a much later chronological age than their peers. Although differences were found for direction, these differences were seen in adults with CP and age matched adults. In the current study, adults with spastic diplegic CP had a greater level of performance variability, which was not as evident in the age-matched adults. This difference may be directly related to the position of the participant; the current study had participants standing rather than in a seated position. As noted earlier, the issues of balance and a shifting of weight during the movement may increase task complexity and affect reaction time in the contralateral direction. This instability may have affected the adults without CP as well.

**Movement Time**

Significant differences were also observed in overall movement time between the two groups; specifically, participants with spastic diplegic CP are slower than their age-matched peers. No differences in direction are found for either group. Once the initial processing is accomplished, movement of the leg in the contralateral direction is no more complex than movement in any other direction. McLellan and Drowatzky (1993) reported overall differences in MT between participants with spastic CP and age-matched peers. Parks and colleagues utilized a population of adolescents (12–16 years) and noted that MT was slower for individuals with spastic CP than the control group. Other than the current study, no investigations have evaluated the lower extremity in adults with spastic diplegic CP. As with the aforementioned studies as well as our data, MT may simply be slower due to postural control or the level of spasticity found in the muscles.

**Conclusions**

Spastic diplegia is the most common form of CP and is characterized by greater involvement of the lower extremities (Watt, Robertson, & Grace, 1989). Physical declines in adults with CP may be due to years of altered movement patterns. Murphy and colleagues (1995) reported that adults with CP were able to ambulate independently as adolescents but lose this capacity as an adult. A deterioration of postural and ambulation skills is a serious problem in adults with CP and this decline may be seen at an earlier age than in adults without disabilities (Jahnsen et al., 2004). There is a need to determine factors that precipitate this decline. There is a critical need for objective evaluation of motor performance. Reaction and movement time measurements provide objective quantifiable data of neuromuscular
performance. The midline crossing protocol is highly reliable in a population that exhibits movement disparities. This protocol could be used to assess changes over time or improvement due to training. It would be advantageous to have a quantifiable measurement tool that could assess the effectiveness of various rehabilitation protocols based on pre and post testing information. In addition, there is limited knowledge in the literature regarding adults with CP and their performance on motor skills. Therefore, more research is needed to understand the factors that affect aging in the adult with spastic diplegic cerebral palsy.

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