Analysis of Upper Extremity Movement in Four Sitting Positions: A Comparison of Persons With and Without Cerebral Palsy


Key Words: cerebral palsy • movement disorders • posture

The purposes of this study were to compare the arm movements of persons with and without cerebral palsy and to determine if the alteration of the seat angle of a chair affected the quality of those movements. Twelve subjects—3 men and 3 women with spastic cerebral palsy and 3 men and 3 women without any known anomalies that could affect arm movements—were studied. The number of movement elements constituting a reach was used to measure the quality of movements. The findings demonstrated significant differences in the number of movement elements used by the subjects with and without cerebral palsy regardless of position. No significant differences could be attributed to the seating positions. Implications are discussed in relation to the method used in the analysis of movements and the effect of the findings for research and treatment.

Adaptive positioning for clients with cerebral palsy or brain injury is often used by occupational therapists as an adjunctive mode of therapeutic intervention. A therapist may plan an adaptive seating program with three assumptions in mind: (a) that the program will lead to a reduction in abnormal postural muscle tone (Nwaobi, 1986; Nwaobi, Brubaker, Cusick, & Sussman, 1983; Seeger, Caudrey, & O’Mara, 1984), (b) that the reduction in abnormal tone will increase the clients’ ability to stabilize their posture (Nwaobi, 1986; Nwaobi et al., 1983; Seeger et al., 1984), and (c) that the increase in postural stabilization will result in an increased ability to control the upper extremity (Noronha, Bundy, & Groll, 1989).

Anecdotal support of the affects of postural stability on reach may be found in Bower’s (1972) study conducted with neonates. Bower suggested an ideal chair angle: one that provided postural stabilization and that freed the infant’s arms and head, thereby allowing the newborn to accurately direct his or her arm movements. Although there have been some investigations of the relationship between postural alignment and adaptive seating (Bardsley, 1984; Boothby, 1984; Brunswic, 1984; Dunkel & Trefler, 1977; Montgomery & Cashin, 1985; Waksvik & Levy, 1979), few experimental studies have attempted to investigate whether adaptive sitting leads to normalization of muscle tone or an improvement in limb control.

Five research studies investigated these assumptions with persons with cerebral palsy. Two of these studies attempted to determine if there was an alteration in muscle tone when persons with cerebral palsy were positioned with different seating adaptations (Nwaobi, 1986; Nwaobi et al., 1983). Three studies investigated whether there were alterations in the control of arm or hand movements (Noronha et al., 1989; Nwaobi, 1987; Seeger et al., 1984).
Two studies (Nwaobi, 1986; Nwaobi et al., 1983) used electromyographic (EMG) methods. The researchers proposed that increases in the magnitude of the EMG response of the postural muscles of persons with cerebral palsy would indicate increasing levels of abnormal muscle tone. Both studies reported that the EMG response was minimal when the seating surface was parallel to the floor. A shift in the angle of the seat (anterior or posterior tilt) or backrest increased muscular activity. The results of these studies are questionable because the methods used to quantify the EMG recordings were not adequate as measures of muscle tone (Katz & Rymer, 1989) and because the rationale that an increase in EMG activity is a negative sign and a decrease is a positive sign is unfounded (Mills & Quintana, 1985).

Seeger et al. (1984) investigated the ability of persons with cerebral palsy to accurately maintain a light on a target with a joystick control. Two groups of subjects, one with extensor dominant tonal patterns and the other with flexor dominant patterns, were positioned in a sitting posture. The effects of posterior tilt of the seat with the former group and anterior tilt of the seat with the latter group were compared to a no-tilt condition. The findings demonstrated that the seat angle did not alter the subjects' ability to direct the light accurately.

Nwaobi (1987) found that arm movements were significantly faster when subjects with cerebral palsy were positioned in a seat with a backrest angle of 90°. The subjects were required to abduct their arms as fast as possible, moving a dowel along a curvilinear track. Slower speeds were recorded when the subject's seat was tilted in an anterior direction.

Noronha et al. (1989) compared the effects of seating and prone standing. They tested subjects with cerebral palsy on the Jebsen-Taylor Hand Function Test (Jebsen, Taylor, Trieschmann, Trotter, & Howard, 1969), which generally assesses the time to completion of eight simulated functional tasks, and with a test they developed to assess the quality of grasp. The subjects performed the Small Objects subtest significantly faster while in the seated position. They performed the Simulated Feeding subtest significantly faster in the standing position. More atypical grasping patterns occurred during the performance of the simulated feeding subtest in both positions. The authors noted that the underlying assumptions of the treatment rationale may need further study. They observed that the effects of positioning might be specific to an activity and that their participants exhibited stress, which may have confounded results.

The findings reported by these three studies are contradictory, possibly because each used a different dependent measure. Rosenbaum, Russell, Cadman, Gowland, and Hardy (1990) discussed the problems in identifying sensitive, dependent variables for studies with this population. All three studies used product measures, while the changes that might immediately occur in the response to treatment may be more qualitative (Kluzik, Fetters, & Coryell, 1990).

High-speed cinematography or videography may allow for a quantitative analysis of qualitative movement changes and can be used to analyze the process or underlying mechanism of change, as opposed to the product of change (Kluzik et al., 1990; Shellenkens, Scholten, & Kalverboer, 1983). This technique has been demonstrated to be effective in the assessment of changes in arm movements of subjects with cerebral palsy (Kluzik et al., 1990) and has been used in analyses of upper extremity movements of infants (Fetters & Todd, 1987; Von Hofsten, 1979).

The dependent measure used in this type of analysis is the movement element (Shellenkens et al., 1983; Von Hofsten, 1979) or the movement unit (Fetters & Todd, 1987; Kluzik et al., 1990). A movement element has been operationally defined as one wave of acceleration or deceleration of a particular magnitude (see Figure 1). Theoretically, it represents a preprogrammed segment of a movement that cannot be altered by feedback (Von Hofsten, 1979) or a point in a movement where the trajectory is shifted from a straight path toward a target (Fetters & Todd, 1987). The number of movement elements that comprise a reach, therefore, is indicative of the curvature, shifts in trajectory, or direction (the correction) of a preprogrammed plan.

The purposes of the present study were (a) to
determine if the number of movement elements of subjects with cerebral palsy during reach was greater than the number used by a population of non-neurologically involved subjects and (b) to determine if any one of four adaptive seating positions immediately altered the number of movement elements used among either group. Because Shellenkens et al. (1983) demonstrated the number of movement elements constituting the reach of children with learning disabilities was greater than normal, a directional hypothesis could be made. We hypothesized that the subjects with cerebral palsy would similarly use more movement elements in their reach.

Method

Subjects

Twelve subjects, 3 men and 3 women with spastic cerebral palsy and 3 men and 3 women with no known pathological conditions that would affect movement, volunteered for this study. All of the subjects were between 18 and 21 years of age and were right-hand dominant. The subjects with cerebral palsy were residents of an institution for persons with mild or moderate retardation. Each of these 6 subjects had mild to moderate spasticity. All 6 could follow the experimenter's directions.

Equipment

A Rifton model E50 adjustable chair1 and an Everest and Jennings model P8AU60–618–770 wheelchair2 were used for the subjects' seating. The Rifton chair allows for alteration of the backrest, seat, armrests, leg rests, and reclining angle. A triangular wedge made of foam and wood covered with Vinyl was used to alter the seat angle from neutral to a 15° anterior tilt or a 15° posterior tilt.

An intermittent-frame, 16-mm, high-speed, 10-cam camera fitted with a zoom lens was used to film the performance of the reaching task. A Numonics3 digitizer was used to digitize data by hand for a frame-by-frame analysis. The W.BIOMECH 87 software program (University of Waterloo, Biomechanics Department, 1987) was used to determine velocities and accelerations of movements. This program filtered the digitized data at 5 hz with a zero-lag, second-order, low-pass digital filter. Two high-intensity tungsten lights were used to illuminate the field of view for filming.

Simple electrical light cues and switch mechanisms were made to indicate to subjects when they should begin to reach and to the experimenters both when the arm began to move and when reach had been completed.

Setting

The adaptive chair or wheelchair was placed at the rear of a room (see Figure 2). The chair was positioned and the subject seated to film the movement of the right arm in a sagittal plane. The camera was placed 9 m from the subject across the room. The two high-intensity lamps were on the right and left sides of the room, half the distance from the camera to the subject. The lights were directed at the ceiling. Only reflected light illuminated the subject, which did not interfere with vision during reach. EMG data were collected for other experimental purposes (Spaulding et al., 1990). Surface electrodes, which were placed on the subject's arm, were connected to a preamplifier, amplifier, and computer positioned so as not to interfere with reaching movements. A small light, placed in front of the subject at eye level and switched on and off by the camera operator, served to signal the subject when to begin to reach. A pressure-sensitive switch, which was placed on the armrest of the wheelchair and positioning chair, indicated when arm movement was initiated. A dowel (split lengthwise with a pressure-sensitive switch in the middle) was placed at arm's length (a distance of the first palmar crease for each subject when the shoulder was at 90° flexion and the elbow was in full extension) in line with the subject's hand. The cue light and the two switch mechanisms were connected to a box containing three lights. This box, placed in the camera's field of view, signaled the end of the reach and indicated to the experimenters when the camera should be stopped.

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1 Available from Rifton—For People With Disabilities, Rifton, NY 12471.
2 Available from Everest and Jennings, 1803 Pontius Avenue, Los Angeles, CA 90025.
3 Available from Lafayette Instruments, PO Box 5729, Lafayette, IN 47903.

Figure 2. The experimental setting. Note. The Rifton chair is available from Rifton—For People With Disabilities, Rifton, New York 12471.
of view, indicated when each event occurred to allow for film synchronization with the movement.

Procedure

Blue dot markers were affixed to anatomical landmarks of each subject prior to filming, to allow for hand digitization and to define segment center of mass positions from filmed data. The markers were placed on the subject at appropriate places so as to define the upper arm, forearm, and hand segment according to the procedures recommended by Winter (1979).

The subjects were seated in the two different chairs (i.e., the positioning [adapted] chair or the wheelchair) for four experimental conditions. In Condition 1, the seat-to-backrest angle of the positioning chair was kept at 90°. In Condition 2, the wheelchair was used. In Condition 3, a triangular wedge was placed in the seat of the positioning chair to encourage 15° of posterior tilt at the hip. In Condition 4, the triangular wedge was placed in the seat of the positioning chair to encourage 15° of anterior tilt at the hip. An occupational therapist certified in neurodevelopmental treatment theory monitored all position changes for the persons with cerebral palsy. This therapist ensured the adequate height of armrests, leg and foot support, and hip and trunk stability. The actual positions except for seat angle alterations were individualized for each subject. This therapist was also familiar to all of the subjects with cerebral palsy and served to counteract the unfamiliarity of the surroundings. The four conditions were presented in a counterbalanced fashion. All subjects had 10 practice trials in Condition 1 prior to data collection and experimental manipulation. Data collection proceeded as follows (see also Figure 2):

1. Investigator 1 turned on the camera, ensuring that it reached 100 frames per sec.
2. Investigator 2 turned on the high-intensity lights upon receiving a verbal cue from Investigator 1.
3. Investigator 3 began recording EMG activity when the lights were turned on.
4. Investigator 1 turned on the switch that provided the subject with a cue to begin to reach.
5. The second light cue was triggered when the subject’s arm began to move from the armrest, indicating the beginning of reach.
6. Investigator 1 indicated data collection had been completed when the third light cue was triggered by the subject’s grasping the dowel.

Data Reduction

Accelerations and decelerations were hand plotted. The number of movement elements per reach was determined by a visual analysis of plotted data. A movement element was counted when one wave of acceleration or deceleration of at least 4 cm per sec² passed from a positive acceleration, through the 0 m per sec² value on the x-axis, and returned to or passed through the 0 m per sec² value on the x-axis. This is consistent with Von Hofsten’s (1979) definition but slightly different from the definition used by Kluzik et al. (1990), whose criterion required greater shifts in values. Movement elements were counted separately for all three limb segments, thus distinguishing this study from previous research, which has only looked at the hand.

Experimental Design

This study was quasi-experimental. Two main effects were planned to be analyzed. The first was the differences between the two groups, which involved a random analysis. The second was the difference between conditions among subjects with and without cerebral palsy, which involved a repeated-measures component. Because the sample was small and no justification could be found to suggest the normal distribution of movement elements, a Friedman two-way analysis of variance (ANOVA) was chosen to analyze the data. This is analogous to the two-way ANOVA for one repeated measure for ordinal data. It required analysis of the non-repeated-measures component with a Kruskal-Wallis test and the repeated-measures component with a Friedman test (Marascuilo & McSweeney, 1977; Serlin & Marascuilo, 1989).

![Figure 3. Velocity and acceleration of the upper arm, forearm, and hand. (a) Subject 4, control group (i.e., without cerebral palsy), wheelchair position; (b) Subject 4, experimental group (i.e., with cerebral palsy), neutral position.](http://ajot.aota.org/)

February 1991, Volume 45, Number 2
Results

Figure 3 illustrates the velocity and acceleration patterns for the three limb segments of two subjects—one with and one without cerebral palsy. The differences in the smoothness of the velocity and acceleration curves are immediately evident in this trial. Differences in the number of movement elements per reach when the subjects with cerebral palsy were compared with the subjects without cerebral palsy were confirmed by statistical analysis (see Table 1). The Kruskal–Wallis test was significant \( (H = 15.32; p \leq .05) \). It should be noted there was a particularly large range (4 to 26) in the number of movement elements for the subjects with cerebral palsy. The number of movement elements for the group without cerebral palsy ranged from 3 to 14. This would indicate overlapping distributions.

The positioning of subjects in the four conditions did not seem to alter the number of movement elements used in reaching consistently. The Friedman test demonstrated there were no significant differences due to position \( (H = 1.57, p > .05) \). The range of movement elements for 9 subjects was \( \leq 4 \) (Subjects 1, 2, 3, 4, and 6 in the group with cerebral palsy; Subjects 1, 4, 5, and 6 in the group without cerebral palsy); for 3 subjects, >7 (Subject 5 in the group with cerebral palsy; Subjects 2 and 3 in the group without cerebral palsy).

Because significant differences were found between the two groups, a further data analysis was conducted. The number of movement elements for all four trials for each limb segment was compared (see Table 2).

A Kruskal–Wallis test was performed at an alpha level of .10 for a two-tailed test (.05 alpha level for one-tailed test). This was justified because it could be predicted that the group with cerebral palsy would demonstrate more movement elements than the control group. However, this increases the Type I error rate for this test to 1 chance in 10. The analysis demonstrated that significant differences did exist on the omnibus test \( (H = 6.70, p \leq .05 \text{ for a one-tailed value}) \). Post-hoc comparisons were accomplished with the two sample Wilcoxon tests (Marascuilo & McSweeney, 1977). We found that the differences between the two groups could be attributed to differences in the number of movement elements of the hand and forearm, but not of the upper arm.

Discussion

The subjects with cerebral palsy used more shifts in acceleration and deceleration in the same reaching task than did the subjects without cerebral palsy, which indicates that their movements were less programmed (Von Hofsten, 1979) or had more trajectory shifts on the path to the object (Fetters & Todd, 1987). Shellenkens et al. (1983) demonstrated a similar finding in comparing the reaching patterns of children with learning disabilities to those of children without learning disabilities. They suggested that the children with learning disabilities might be using more visual feedback and control during movement than their non-learning-disabled counterparts. This in turn

Table 1

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Note. For comparison between the two groups, \( H = 15.32, \chi^2(1, 95) = 3.84, p < .05 \) (two-tailed). For all four conditions, \( H = 1.57, \chi^2(3, 95) = 7.81, p > .05 \) (two-tailed).
slowed down the movement and caused the children to correct their movements more frequently on the way to the target. Kluzik et al. (1990) suggested that the discontinuous nature of the reaching among their subjects with cerebral palsy was an indication of the use of a less mature pattern. We cannot, however, determine support for either contention on the basis of the data we have collected.

EMG findings reported elsewhere would suggest that the subjects with cerebral palsy had different power frequency spectrums that comprised their movement (Spaulding et al., 1990). That is, more low-frequency components and fewer high-frequency components of muscle activity were noted among the subjects with cerebral palsy. This could be due to hypertrophy of Type 1 muscle fiber and atrophy of Type 2 muscle fiber or a dramatic increase in fatigability of the Type 2 muscle fiber of the group with cerebral palsy.

The sitting positions did not alter the quality of the reaching movements, consistent with the findings reported by Seeger et al. (1984) but inconsistent with Nwaobi's (1987) study. Comparison of the present study with Noronha et al.'s (1989) study is difficult because the latter compared the differences in the speed of movement in two different positioning devices. The findings from the present study would raise the same theoretical issues identified by Noronha et al., that is, (a) Are the underlying assumptions of this treatment approach valid? and (b) Are the effects of positioning situationally specific? Three additional concerns need to be addressed. First, the range of scores within the group with cerebral palsy would indicate that movement difficulty was heterogeneous. At least one subject within the group with cerebral palsy (Subject 1) demonstrated patterns of movement that could not be distinguished from the movements of the control group (i.e., the group without cerebral palsy) (based on this type of analysis). Subjects 2 and 3 in the group with cerebral palsy also had profiles that overlapped with those of the control group. Second, all of the subjects in the cerebral palsy group were mildly to moderately impaired. Was this the best population to use to test this hypothesis? Would a more severely impaired population produce different results? Third, this study only investigated the immediate effects of positioning. All of the studies that we have cited have investigated only immediate efficacy. Would different results have been evident if the investigation had been longer? The negative findings obtained could have been due to any one of these factors individually or in combination. The results of this research, however, would suggest that positioning to improve upper extremity function is not applicable in all cases and is questionable as an indiscriminate method. It is also important to note there are more reasons for positioning (e.g., prevention of deformity, compensation for a lack of postural stability) other than improving upper extremity function.

The inferences that can be drawn from this study are limited by the sample size. We believe it is possible that the results may have been different if a larger sample had been used.

The use of high-speed cinematography as a measurement instrument to detect differences in movements between persons with and without cerebral palsy was supported. This type of instrumentation and method of analysis could describe the qualitative movement disorder of the neurologically impaired group in a quantifiable manner. This technique, if further refined, might be useful in the clinic to more completely identify a person's problem in reaching. Such findings may become a foundation for treatment planning. For example, careful inspection of Figure 3(b) would indicate that the movements of the upper arm and forearm were disturbed but that the hand movements exhibited more shifts in acceleration and deceleration. The subject started moving with the hand. The forearm movement into full extension was least disturbed and the upper arm movement was very abrupt and then generally quiet. Proximal control for this subject does not seem to be as much of a problem as distal control. This is not evident on visual inspection of the reaching movement and may have been characteristic of this sample of subjects with cerebral palsy. The number of movement elements of the hand and forearm was significantly different from that of nondysfunctional subjects. This was not true for the movement elements of the upper arm, which may indicate that these subjects would not benefit from a positioning program to increase upper extremity function—perhaps an important area for future research. More data are needed to confirm this speculation.

**Summary**

The findings of this study suggest that there are quantifiable, qualitative differences in reaching between subjects with and without cerebral palsy. Positioning in any of four positions did not consistently alter the quality of the arm movements of the subjects with and without cerebral palsy. A wide range in the severity of movement disorders was noted within the group with cerebral palsy. The study's findings might be limited by sample size, the focus on immediate effects as opposed to long-term adaptation of a client to an altered position, and subject selection. More research is indicated to confirm the theoretical foundations for alteration of the seat angle to increase upper extremity function and to further investigate whether more specific subpopulations of persons with cerebral palsy
(e.g., those with more severe impairment or those with more demonstrable upper arm disturbance) may benefit from this mode of intervention.

References


