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Sitting Postural Control Affects the Development of Focused Attention in Children With Cerebral Palsy

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Sitting Postural Control Affects the Development of Focused Attention in Children With Cerebral Palsy

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Abstract

Purpose:

To investigate whether focused attention (FA) changes over time as sitting postural control improves and whether an impairment in sitting postural control affects the development of FA in children with cerebral palsy (CP).

Methods:

Nineteen children with CP, mean ages 21.47 months, were assessed for FA and sitting scores pre- and postintervention.

Results:

Longest, total, and global FA increased and frequency of FA decreased in children who achieved independent sitting. However, children who achieved mobility postintervention exhibited a decrease in longest FA and an increase in frequency of FA.

Conclusion:

Sitting postural control and the development of FA appear associated in children with CP. The increase in FA may signal a key opportunity for learning and attending to objects. However, the time of early mobility may interrupt these long periods of attention, resulting in less sustained attention to objects.

INTRODUCTION

From a “grounded cognition” perspective, infant cognitive development occurs via perceptual-motor experience within a social and cultural context.[1] Motor skills allow infants to explore the environment, to acquire knowledge, and to gain information about their bodies, objects, and people. Reaching and grasping provide opportunities for information gathering and acquiring knowledge about the environment,[2] which then facilitates problem-solving skills.[3] Early perceptual-motor experience gained after achieving independent motor skills such as sitting, crawling, and locomotion facilitates cognitive development in infants who are developing typically.[4] Thus, early perceptual-motor experience gained through object interaction facilitates cognitive development.

A specific example of the interrelation between cognition and action is in the case of focused attention (FA). In general, attention involves processes that allow individuals to focus on particular aspects of the environment and to mobilize sufficient effort for learning and problem solving.[5] Focused attention is the duration of concentrated examination of objects during independent play or object exploration[6]; FA plays an important role in learning by enhancing selectivity and by maximizing the intake and use of information.[7] Early motor skill in the form of exploration and manipulation abilities, prevalent particularly during the latter half of the first year, facilitates the development of FA.[2] Infants born preterm and infants with neuromotor dysfunction show impaired FA as compared with infants who are developing typically.[8–10] Exploration and manipulation skills emerge from the confluence of many factors, including level of postural control,[11] eye-hand coordination,[12] strength of antigravity muscles and the control of upper extremities,[13] experience in performing the task,[14] and knowledge about object affordances[15] and properties.[16] Hence, action provides early opportunities for development of attention and perception.[17]

The most cited reason for impaired reaching, grasping, and manipulation skills in infants with neuromotor disabilities is impaired postural control.[18–20] Infants with cerebral palsy (CP), in particular, may experience poor postural control further impairing eye-hand coordination and object exploration. These motor impairments have a cascading effect on other domains: contributing to delays in development of perception of objects and their properties, which, in turn, may impair early conceptual development.[21] We know a great deal about the development of attention in children who are developing typically and the relationship between cognition and action, yet whether impaired sitting postural control in children with CP negatively affects the development of FA remains unexamined.

The relationship between sitting and FA is likely to be bidirectional, but the relationship has been underinvestigated. By investigating FA during the emergence of sitting, rather than at a specific age, we expected to determine how FA changes during the evolving skill of independent sitting. Hence, the purpose of this study was to investigate whether FA changes as sitting postural control improves, and whether impairment in sitting postural control could affect the development of FA in children with CP. We hypothesized that children with poor sitting postural control would have less FA on objects during exploratory play, and that FA would increase as sitting control improved.

METHODS

This study used archival data collected from 2008 to 2012 from 3 different intervention studies of improving sitting postural control in children with CP.[22–24] Coding of Gross Motor Function Measure (GMFM) scores occurred in the original studies, and coding of videos for FA variables was the new analysis for this study. All GMFM testing was performed by a physical therapist (PT). The GMFM testing was first videotaped and later scored by a PT trained in scoring the GMFM to a reliability of greater than 90% agreement with training tapes. This PT was blinded to the order of GMFM testing. A coder trained in coding of FA with the sequential data analysis software “OpenSHAPA” coded the segments of FA, with intrarater reliability of 0.98 for FA duration and 0.96 for global focused attention (GFA). The coder was blinded to testing order.

Participants

Nineteen children (12 males and 7 females) with the mean age of 21.47 (SD = 10.54) months and mild to moderate CP, ranging from a score of 4 to 5 and 6 to 8, respectively, on our CP severity rating scale (see the Appendix) participated in the study. A severity scale for children with CP was created in our previous study to guarantee equal distribution of children with CP of differing severities.[23] The scale was used in this study to select children with mild and moderate severity of CP. The CP severity rating scale includes 4 main domains: distribution of movement limitation, active movement, Peabody standard score, and GMFCS level. We used this scale previously[23] to ensure equal distribution of children with varying levels of severity in control and intervention groups because the other option, using GMFCS levels, did not adequately describe children younger than 2 years. It was used solely as a descriptor for selection and not as an outcome measure in all studies.

We included children with a diagnosis of CP, a score of mild or moderate severity on our CP severity rating scale, the initial ability to sit with support, and without known visual impairments. Children with a hip dislocation, neuromuscular diagnosis other than CP, severe cognitive deficits, or quadriplegic CP with severe upper limb dysfunction, which could have affected object exploration during play assessment, were excluded from this study. The Institutional Review Board approved the study, and informed written consent was obtained from parents of children prior to data collection and intervention.

Instrument

We originally used a modified Play Based Assessment (PBA) as described by Kelly-Vance and Ryalls,[25] using the Play In Early Childhood Evaluation System (PIECES). Play Based Assessment was a process of observing a child`s skills in the context of play. We used PBA as a tool to facilitate and observe natural behavior in a standard manner, which we assumed would be a reflection of cognitive skills. We coded all variables of FA, using video segments from a modified PBA. An evaluator was a PT trained in PBA who provided age and skill-appropriate toys to children for exploration and manipulation during exploratory play. The toys used for exploratory play were a series of objects, including a toy piano, pop-up toy, pull toy, doll, etc. A variety of toys were presented to accommodate individual interests. The time allotted for exploratory play was 10 minutes during both the pre- and postassessment sessions.

Procedure

A PT made the child comfortable and performed the GMFM assessment in a comfortable setting within the development laboratory. GMFCS was determined prior to the first data collection as part of the invitation to participate in the study. Children sat with support as needed for the first (preintervention) session of play assessment to encourage as much engagement with the toys as possible. Support consisted of an adult sitting behind the child during the play assessment, and providing light to moderate trunk support to help the child remain sitting without using arms for postural support.

We conducted the modified PBA in the presence of the parent. The evaluator presented several toys within a 10-minute period. Two Panasonic Digital Video Cameras (Model DMR-EH75V) were used to film the play session, and a Digital Video Mixer (Model MX—4 DV) was used to combine the views onto 1 screen. The cameras were at the level of the child and positioned to record a front view and a side view of the child. These videos were later coded for FA.

We measured FA by timing periods of intense concentration on specific objects, which is a reliable and valid method to measure FA in children.[26] Although the total exploratory playtime varied, a trained coder used only the initial 90 seconds after the presentation of each toy to measure FA. The same trained coder measured FA throughout the infants' exploration of 3 novel toys (each 90 seconds) using the exploratory sequential data analysis software, “OpenSHAPA,” an open-source research tool, to measure the following:

1. Global focused attention. This qualitative rating ranged from 1 to 5, with 1 indicating no clear evidence of interest in the objects, and 5 representing a longer period of absorption, and action on the objects with long episodes of FA and reduced extraneous behaviors.[27] A child looking steadily at the toys with serious and intent expression and affect marked the beginning of FA, and a child looking away from the toys marked the end of FA. We analyzed GFA, along with other quantitative measures of FA such as longest FA, total FA, and frequency of FA, because GFA is more feasible for a clinical setting and more readily generated than the quantitative measures, which require specialized recording and considerable time. In addition, GFA may capture several relevant variables in a single score.[28]
2. Longest FA measured the longest time period of sustained attention for each of 3 toys within the 90 seconds of toy exposure.
3. Total FA for the complete session, which consisted of the duration of total time that the child concentrated on the objects while exploring the objects within the total play assessment of 270 seconds (90 seconds each for 3 toys).
4. Frequency of FA, providing a count of the number of times the child was concentrating on each toy during the complete play session. Only periods of FA more than 2 seconds were included for the analysis of longest FA, total FA, and frequency of FA.

After the exploratory play session, we administered the sitting subsection of the GMFM, to quantify sitting postural control. After the initial assessment, children received intervention to advance sitting postural control, which was part of a larger research study from which these data were drawn. An experienced PT who was a Pediatric Certified Specialist (PCS) delivered the interventions in a variety of settings. The overall goal of intervention was to improve sitting postural control in children with CP, but the interventions varied in approach (perceptual-motor training,[23,24] home program,[23] and body weight-supported training[24]), with an intensity of 45 to 60 minutes, duration of 8 to 12 weeks, and frequency of 1 to 2 sessions per week. Perceptual-motor training emphasized an ecological approach and a focus on spontaneous movement, rather than facilitated movement, based on environmental affordances. Self-initiated, functionally directed movement was the focus of intervention.[23,24] In the home program caregivers received written suggestions, individualized goals, and verbal instructions/demonstration.[23] Body weight support training emphasized assisting the child by lifting the body segments (trunk, legs) through patterns of movement.[28] Attrition was the same for all subjects, everyone completed the assigned intervention, and there was no loss of follow-up within the study duration. All families were present for the interventions when the therapist interacted with the child, but carryover by caregivers was not assessed. Regardless of the intervention approach, all children assessed for this study achieved the same progression toward development of independent sitting. All children were assessed for global FA, longest FA, total FA, and the frequency of FA at the beginning stage of sitting, and once sitting had been achieved. We used the same method of coding and analysis of FA and again administered the GMFM sitting section to obtain postintervention FA and GMFM sitting scores. A single PT who was blind to the pre-/poststatus of the video scored the GMFM tapes. The intrarater reliability of GMFM scoring was 0.90.

STATISTICAL ANALYSIS

All statistical analyses were performed using SPSS software (version 21.0). The α level was set at .05. First, the individual longest FA during the 90-second exploration for each of the 3 toys (90*3 = 270 seconds) was averaged to obtain the average longest FA. Total FA was obtained by adding all FA time during 270 seconds of object exploration for each subject to obtain pre- and postintervention values. Data were not normally distributed for the longest FA, total FA, global FA, frequency of FA, and GMFM; therefore, we used the nonparametric Wilcoxon signed ranked test to compare pre- and postvalues of these variables. General linear model procedures were used to assess group × time changes in total attention behavior, with the groups defined as those children who achieved independent sitting, and the group who achieved independent mobility postintervention. An interaction effect between the change in total FA and the GMFM score was analyzed with pre- and posttotal FA as within-subject factors and mobility as between-subject factors. Data were examined for Sphericity and a Greenhouse-Geisser *F* test was used to test for a main effect in changed total FA and for interaction effects between changed total FA and mobility skill.

RESULTS

We report in each of the following sections all FA variables and GMFM sitting scores postintervention first for all children (children sitting independently and children who were mobile postintervention), then for children sitting independently only, and finally for children who were mobile.

Longest Focused Attention

Across the 270-second total exploration of 3 toys (90 seconds each), the mean longest FA for all children during play preintervention was 49.94 (SD = 23.07) seconds; postintervention, the mean longest FA was 57.45 (SD = 18.21) seconds, which did not differ significantly ($P < .1$). However, of 19 children, 4 children with CP progressed to mobility (crawling), whereas 15 did not crawl but did achieve independent sitting postintervention. We then removed the 4 children who were mobile from the main analysis because their data appeared to be showing a different behavior.

Analysis of the children sitting independently showed a significant change in the mean longest FA from 45.04 (SD = 22.66) seconds during nonindependent sitting preintervention to 57.58 (SD = 18.68) during independent sitting postintervention, which was statistically significant ($P < .02$). Further analysis of longest FA in the 4 children who were mobile (crawled) at the postintervention testing showed a significant decrease in longest FA from 68.39 (SD = 15.20) to 54.02 (SD = 16.59) postintervention ($P < .04$), reflecting a different behavior when compared with the children who did not demonstrate independent mobility.

Total Focused Attention

Total FA for all children changed from 181.33 (SD 50.31) seconds preintervention to 216.65 (SD = 27.46) seconds postintervention, which was statistically significant ($P < .009$). Total FA for children who were independently sitting increased from 179.20 (SD 52.07) seconds preintervention to 211.92 (SD 45.43) seconds postintervention, which was statistically significant ($P < .005$). Moreover, separate analysis of total FA for children who were mobile showed that total FA decreased from 245.85 (SD = 9.60) seconds preintervention to 231.78 (SD = 23.82) seconds once they achieved mobility postintervention. However, this decrease in total FA postintervention in children who were mobile was not significant ($P < .169$).

Global Focused Attention

Global FA for all children changed from 3.70 (SD = 0.97) preintervention to 4.27 (SD = 0.55) postintervention, showing statistical significance ($P < .007$). Global FA for children sitting independently showed a significant change from 3.48 (SD = 0.95) preintervention to 4.24 (SD = 0.59) postintervention ($P < .003$). Global FA for children who were mobile changed from 4.50 (SD = 0.57) preintervention to 4.41 (SD = 0.41), which was not statistically significant ($P < .6$).

Frequency of Focused Attention

Frequency of FA for all children changed from 14.18 (SD = 3.79) preintervention to 13.56 (SD = 4.51) postintervention, which was not significant ($P < .8$). However, after excluding the children who were mobile, the frequency of FA for children sitting independently decreased from 14.20 (SD = 4.27) preintervention to 12.66 (SD = 4.79) postintervention, which was statistically significant ($P < .004$). Frequency of FA in children who were mobile increased from 8 (SD = 2.44) preintervention to 13.75 (SD = 5.50) postintervention, which was statistically significant ($P < .04$).

Gross Motor Function Measure—Sitting Subset

The sitting scores of GMFM for all children changed significantly ($P < .001$) from 23.21 (SD = 8.33) during preintervention to 38.47 (SD = 11.41) during postintervention. The change in GMFM sitting scores for children sitting independently was from 21.60 (SD = 8.24) preintervention to 36.13 (SD = 9.60) postintervention, which was statistically significant ($P < .001$). The GMFM sitting scores for children who were mobile changed from 29.25 (SD = 6.18) preintervention to 47.25 (SD = 14.86) postintervention, which was statistically significant ($P < .02$).

Interaction Between FA and Postintervention Sitting Outcomes

A 2 (intervention session) × 2 (mobility group) ANOVA on total FA revealed a significant interaction between session and group ($F_{10.07}$, $P < .006$). Total FA changed from 181.88 to 229.49 seconds from nonindependent sitting preintervention to independent sitting postintervention. However, total FA decreased from baseline 222.09 to 209.92 in children who progressed to crawling.

DISCUSSION

We asked 2 questions in this first study examining the development of FA in relation to the development of sitting postural control in children with CP. First, does FA change over time as sitting postural control improves? Second, does impairment in sitting postural control affect the development of FA in children with CP? The results of this study suggest: first, sustained attention, measured by longest FA on objects, increases over time as sitting postural control develops. As sitting postural control advanced from supported sitting to independent sitting, sustained attention on objects during exploratory play increased linearly. Second, the linear change in sustained attention with the improvement of sitting postural control showed a different trend in a few children who achieved mobility. A change in sustained attention on objects occurred with more breaks occurring in attention as mobility emerged. Third, the total duration of FA and global FA showed a linear improvement in children who were mobile, similar to children who were sitting independently. However, children who were mobile showed frequent short duration bouts of attention, which contributed to an increased total duration of FA, compared with children who were sitting independently. Finally, impaired sitting postural control appears related to the development of FA in children with CP. Moreover, FA appears to increase with the improvement in sitting postural control, suggesting an association between motor and cognitive function.

In our first hypothesis, we predicted that sustained attention would increase as infants achieved independent sitting postural control. The study results clearly supported this hypothesis. We found that mean longest FA significantly improved as children progressed to independent sitting. The achievement of stable sitting postintervention leads to successful object manipulation, which appeared to increase knowledge about properties of objects and, concurrently, increased FA.[17] This finding supports previous studies also suggesting that attention develops through object exploration.[2,29]

We speculate that longest FA may increase as sitting becomes independent because of a gradual shift in the allocation of resources from the initially challenging control of the sitting posture to the task of focusing on objects once sitting is more automatic. Several studies have shown that higher-level cognitive functioning and motor control may compete for limited attentional resources. For example, in a series of locomotor tasks requiring attention for choosing an efficient path, 13-month-old infants' perseverative errors increased as motor demands increased.[30] Theoretically, more resources were devoted to the motor components of the task, leaving insufficient attentional resources available for the execution of the cognitive component of decision making.[30,31] Similarly, when infants had to execute a complex reach, they made more perceptual processing errors than when they executed a simple reach.[32] In our study, children with CP had impaired sitting postural control, which demanded attention to ensure stability. We assume that limited attentional resources were available for focusing attention on the objects. As children achieved independent sitting postural control, we assume that the initially competing attentional resources could be diverted to the cognitive task of FA. Importantly, children showed increased sustained attention on the objects after achieving independent sitting postural control. However, this trend of a linear increase in sustained attention with stable sitting changed with the emergence of mobility.

Children who achieved mobility postintervention showed a decrease in sustained attention. As children moved out of the sitting position, their exploration of the surroundings broke the stream of sustained attention. This change in FA can be attributed to the change in perceptual experience associated with locomotion.[4] Our finding of a decrease in sustained attention with newfound mobility is consistent with evidence that infants engaged in locomotion attended to distal objects and events more often than infants who are not yet locomoting.[33–35] Previous studies examined infant attention during locomotion, whereas infants in the present study showed changes in attention during a nonlocomotor task as a by-product of their newfound locomotor skill. Hence, the independent practice of focusing attention in the direction of motion during crawling may have provided infants who are locomoting the experience necessary to deploy their attention in a discriminating way, and also explain why the longest FA scores decreased in children who had achieved independent mobility in this study.

In addition to attentional deployment in children who were mobile, total duration of FA and global FA postintervention decreased although the change in total and global FA from pre- to postintervention was not statistically significant. Moreover, children who were mobile showed a significant increase in the frequency of FA postintervention. A decrease in longest, total, and global FA and an increase in frequency with shorter duration of attention bouts in children who were mobile postintervention indicated that sustained attention on objects decreases with the emergence of mobility in children. However, children sitting independently showed significant increases in total and global FA and a decrease in frequency of FA postintervention. A few looks of long duration could contribute to an increase in total FA. We found that the increase in total FA in the independent sitting group was a result of the longest bouts of sustained attention and a decrease in frequency of looks to objects. The decrease in frequency likely reflects the tendency for children to focus more on objects as sitting postural control improved. Our results are consistent with previous work, which found that the duration of examining objects increased, and the frequency decreased over time with increasing age.[7]

The results of this study confirm our second hypothesis that an impairment in sitting postural control affects the development of FA in children with CP. Preintervention, when children were sitting with support, the GMFM sitting score was significantly lower compared with postintervention when children achieved independent sitting postural control. Similarly, the longest and total FA changed from pre- to postintervention as children progressed from supported to independent sitting. In our study sample, the baseline FA was lower than expected for the child's age.[26] Hence, the change in FA with age as seen in infants who are developing typically is unlikely.[36] We attribute the significant change in FA to the change in sitting postural control. The change in cognitive skill (FA) with the change in motor skill (independent sitting postural control) indicates an association between motor and cognitive functions and supports the concept of grounded cognition.[1]

This study has potential clinical implications, as it suggests that motor development is associated with the development of attention, a component of cognitive function. Interventions directed to improve motor function may have an effect on components of cognitive function. Evidence suggests that the development of early attention predicts later cognitive and behavioral functioning.[3] Therefore, early training of sitting postural control may be one influence on the development of attention and school performance in children with CP.

A limitation of the study was the lack of either a control group of infants who are developing typically or a group of infants with CP not receiving intervention. However, a nonintervention group for infants with CP would not be possible. Although several interventions were employed, the focus of this study was the development of sitting in all of the children. This is a first step in demonstrating to clinicians the importance of understanding how motor skill development interacts with attention. Future studies, designed to measure how specific interventions relate to attention and cognition, are necessary to improve early intervention. Future research should also examine the development of FA longitudinally with the development of gross motor skills such as sitting, crawling, and walking in both infants who are developing typically and infants with delays. This study suggests that therapists need more evidence about how motor and cognitive skills interact, which will eventually lead to improvements in intervention.

CONCLUSION

Impaired sitting postural control likely affects development of FA in children with CP. Changes in attention coinciding with improved sitting postural control suggest an association between motor and cognitive functions, supporting the concept of grounded cognition. Interventions directed to improve motor function may be related to aspects of cognitive function, which should be considered as part of decision making in early intervention.

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Appendix

Distribution of CP	Quadriplegic	Diplegic	Hemiplegic
Active movement	Low	Moderate	High
Peabody standard score	1-2	3-4	5-8
GMFCS	4	3	1-2

Severity of CP Rating Scale

Scores from each row are totaled for a final severity score: 9 to 12, severe; 6 to 8, moderate; 4 to 5, mild. Below are explanations of each category.

The Gross Motor Function Classification System classifies the motor involvement of children with CP on the basis of their functional abilities and their need for assistive technology and wheeled mobility. Children from classification levels 3 and 4 were the most likely candidates for this study. Level 5 was excluded because these children were unlikely to have the head control needed to meet the entry-level sitting criteria.

Active movements were rated by the clinical judgment of the therapist. High indicates active movement in all limbs with good differentiation of the joints, moderate indicates less than full range of movement of the limbs and movement is performed without differentiation of the joints, and low indicates very little movement and excursion of the limbs.

The Peabody score is the standard score of the gross motor portion of the Peabody Developmental Motor Scales, done to qualify the child for entry into the study and establish a delay from normal motor progression.

Distribution refers to the distribution of movement and muscle tone impairments across the body segments. Quadriplegic is all 4 extremities, diplegic is lower extremity involvement greater than upper extremities, and hemiplegic is involvement of the extremities on one side of the body.