Fall 2005

The Influence of Concurrent Cognitive Tasks on Postural Sway in Children

Yvette Blanchard
Sacred Heart University, blanchardy@sacredheart.edu

Shannon Carey

Jocelyn Coffey

Alison Cohen

Trisha Harris

See next page for additional authors

Recommended Citation

Blanchard, Y., Carey, S., Coffey, J., Cohen, A., Harris, T., Michlik, S., & Pellecchia, G. (2005). The influence of concurrent cognitive tasks on postural sway in children. *Pediatric Physical Therapy 17(*3), 189-193. doi: 10.1097/01.PEP.0000176578.57147.5d

The Influence of Concurrent Cognitive Tasks on Postural Sway in Children

Yvette Blanchard, ScD, PT, Shannon Carey, MSPT, Jocelyn Coffey, MSPT, Alison Cohen, MSPT, Trisha Harris, MSPT, Stephanie Michlik, MSPT, and Geraldine L. Pellecchia, PT, PhD

Department of Physical Therapy, University of Hartford (Y.B., S.H., J.C., A.C., T.H., S.M.) , West Hartford, CT; and Department of Physical Therapy and Collaboratory for Rehabilitation Research, University of Connecticut (G.L.P.), Storrs, CT

Purpose: The purpose of this study was to examine the influence of concurrent tasks on postural sway in children. **Methods:** Nineteen fourth-grade students, while standing on a balance platform, were asked to stand still, count backward, and read second-grade level sentences. The AMTI Accusway System was used to calculate the length of center of pressure path (LCOP), sway range (SR), and variability (SV) in mediolateral (ML) and anteroposterior (AP) directions of sway. **Results:** Analysis of variance revealed a main effect of cognitive task condition for SR-AP, SR-ML, SV-AP, and SV-ML. Post hoc comparisons revealed lower values of those four dependent measures for the counting backward task than for the standing still task and lower SV-AP for the counting backward task than for the reading task. In addition, there was a trend toward greater LCOP when performing a concurrent cognitive task. **Conclusions:** The demands of concurrent cognitive tasks while standing affect postural sway in children. The findings of this study contribute to our understanding of postural control in children and may explain why improvements in postural skills attained in clinical settings may not transfer to improved performance in other settings. **(Pediatr Phys Ther 2005;17:189–193)** *Key words: child, psychomotor performance/physiology, attention/physiology, cognition/physiology, musculoskeletal equilibrium/physiology, posture/physiology, task performance and analysis*

INTRODUCTION

Whether under dynamic or static conditions, postural control is a prerequisite to the maintenance of a wide range of postures and is intimately linked to the control of balance. Postural control is involved in three main types of activities: (1) during the maintenance of a specific static posture, such as standing and sitting; (2) when changing positions or when performing voluntary movements; and (3) when reacting to an external disturbance, such as a push or a slip.[1] Nashner[2] first suggested that posture during quiet standing (a static task) is controlled by sensory feedback using a closed-loop (feedback) system dependent on visual and proprioceptive information. This feedback system appears at a very early age, as confirmed by evidence showing that sensory perturbations can generate postural response synergies in children as young as 15 to 30 months of age.[3] In contrast to this closed-loop system, an open-loop (feedforward) system appears to be used during dynamic tasks. Disturbances in posture are predicted, and the body makes appropriate adjustments through anticipatory postural adjustments to maintain stability.[4] This type of postural control is believed to be reflexive in nature and related to reaction time processes.[5] This system is believed to develop between the ages of six and 10 years, when the child is able to control inertial forces and gravity and move his or her head independently of the trunk.[5]

Traditional views have implied that postural control is automatic, occurs in response to sensory information, and does not require the use of attentional resources.[6,7] Recent investigations, however, provide evidence to the contrary and suggest that postural control involves cognitive as well as sensory processes in the organization and integration of sensory

0898-5669/05/1703-0189
Pediatric Physical Therapy

Address correspondence to: Yvette Blanchard, Department of Physical Therapy, University of Hartford, 200 Bloomfield Avenue, West Hartford, CT 06117. Email: blanchard@hartford.edu

DOI: 10.1097/01.PEP.0000176578.57147.5d

information under both static and dynamic conditions.[8,9] These cognitive processes could include the attention needed to perform the task, arousal, motivation, and judgment.[10] Such a model of postural control may better explain why improvement in postural skills seen in clinical settings does not necessarily transfer to improved performance in other settings. For example, a child with a traumatic brain injury may walk with good balance during his rehabilitation sessions at the hospital but be unable to walk unassisted to the school cafeteria. Huang and Mercer[10] suggest that differences in perceptual, attentional, and cognitive demands of different settings may contribute to the lack of generalization of effects across settings.

Theorists have long attempted to explain the influence of attention on performance. *Limited capacity* theorists working during the 1950s to the 1980s postulated that the brain is capable of processing only a certain amount of information.[7] Thus, a person's performance is not adversely affected when a concurrent task is performed within the brain's available capacity. When the requirements for a certain task exceed the brain's capacity, dual-task interference occurs. These theorists suggested that a process of selective attention is in place as a means of allocating available resources under multitask conditions. These theories were, however, later shown to be inadequate and limited in their ability to predict postural behavior under dual-task experiments[11] and have since lost their popularity.

Since the 1980s, a new theory, known as *selection for action*, has emerged. Its proponents postulate that the ability to allocate attention to tasks has evolved to fulfill functional purposes in order to carry out goal-directed behavior.[12] If two tasks being performed simultaneously involve conditions that are conflicting for their completion, then those conditions are either modified so the task can be performed or one of the tasks is postponed or not completed.[12] Using this concept, Neumann[11] claims that dual tasks are performed concurrently using action planning; the two tasks are combined into one higher order skill. Thus, the performance of a concurrent task will be affected only if the difficulty affects the combined action plan.[11] A study conducted by Pellecchia[7] offers support for this concept. Using a dual-task methodology, the investigator showed that postural sway increased with increasing attentional demands of concurrent cognitive tasks, with the most difficult cognitive task having the greatest influence on sway.[7]

Postural sway, or the displacement of the center of pressure (COP), has commonly been used as a means to measure postural stability and control under static or dynamic conditions. The development of postural sway in children is well documented. Recent research has shown that for children between the ages of 7 and 18 years, sway properties are not affected by changes in body dimensions seen during this phase of rapid physical growth.[13] It has been suggested that the proportional growth of the different body parts and segments during that period would contribute to the unchanging sway properties over time for children within that age group. To our knowledge, no studies have examined how postural sway is directly affected by the attentional demands of a concurrent cognitive task in children. To better address the rehabilitation needs of children with physical disabilities associated with cerebral palsy or traumatic brain injury, it would be important to determine whether concurrent cognitive tasks affect postural sway as seen in the adult population. The purpose of this study was to examine the influence of concurrent cognitive tasks on postural sway during standing in children.

METHODS

Subjects

Thirty-five fourth-grade children from the University of Hartford Magnet School participated in the study. To be eligible to participate, the children had to be between the ages of eight and 10 years, walk independently, be free of any condition affecting their gait or standing balance, and have written parental consent. Fifteen subjects were dropped because of difficulty in following directions during data collection, and one subject's data were outliers. The final sample was composed of 19 children, 12 boys and seven girls, with a mean age of 9.5 years (± 4 months; range, 8 years 8 months to 10 years). None of the children were receiving any type of special education services.

Instruments

Postural sway data were collected using the AMTI AccuSway System for Balance and Postural Sway Measurement (Advanced Mechanical Technology, Inc., Watertown, MA) force platform. The platform measures the applied forces and moments in three dimensions. Data from the platform were acquired and analyzed using Swaywin software (Advanced Mechanical Technology, Inc.) loaded on a Hewlett-Packard laptop computer. The software uses established algorithms to calculate the location of the COP and related variables from the forces and moments applied to the platform. A report of validation tests of data acquisition and analysis of the AccuSway system (AccuSway Plus System validation, Advanced Mechanical Technology, Inc., March 4, 2002) indicated an absolute COP error (which comprises noise, drift, and absolute accuracy) of less than 0.061 cm over a 40-second trial period. Trial-to-trial error due to noise (eg, electrical or mechanical) was found to be 0.025 cm.

Sentences to be read out loud by the children during data collection were displayed via a projection panel appropriate for use with a Hewlett-Packard laptop computer equipped with Power Point software.

Procedure

After obtaining informed consent from the parents, each subject was tested individually in a room reserved for the purposes of data collection at the University of Hartford Magnet School. Subjects were asked to remove their shoes but not their socks. One 15-second practice trial was administered prior to actual data collection for the tasks: standing still, counting backward, and reading out loud.

After the practice trials were completed, the subject was asked to stand on the AccuSway platform to begin data collection. The order of presentation of the three tasks was randomly assigned to control for order effect. During the experiment, subjects performed three 30-second trials of each task. The same instructions were given during the practice and experimental trials with the exception that the practice trials were conducted with the subject standing on the floor instead of the force platform.

For the standing still task, subjects were asked to stand with their feet together and arms alongside the trunk while looking at an image of an animal projected on a wall seven feet away. The image provided a focal point for the subjects while standing. Subjects were instructed to remain still and not move, tug on their shirt or pants, or put their hands in their pockets. For the three trials of the counting backward task, subjects were instructed to stand still while counting backward out loud beginning at number 61, then at 52, and last at 73. Subjects were reminded to keep their arms at their sides and feet together while looking at the projected image on the wall. The reading task entailed subjects standing still while reading second-grade level sentences projected on the wall facing the child at a rate of five seconds for each sentence. Subjects were instructed to read the sentences out loud and not to worry whether there were any words that they did not know. In that situation, subjects were told to skip that word and move on to the next word. Subjects were reminded that their ability to read was not being tested.

Statistical Analysis

Swaywin software was used to calculate the dependent measures: length of the center of pressure path (LCOP), sway range (SR) and sway variability (SV) in anteroposterior (AP) and mediolateral (ML) directions. The LCOP is the distance that the COP travels from its initial position over the 30-second trial period. Figure 1 depicts the path of the COP during a 30-second trial of standing still. Sway range is the difference between the two extreme position values in the specified AP or ML direction. Sway variability is the standard deviation of the COP in the specified direction. Separate 3×3 repeated-measures analyses of variance (ANOVAs) were used to examine the effects of cognitive task (standing still, counting backward, and reading out loud) and trial on each dependent measure. The level of statistical significance was set at $\alpha = 0.05$. Mauchly's test of sphericity was used to ensure that the assumption of sphericity was not violated. When ANOVA revealed significant effects, pairwise comparisons with significance levels, adjusted using the Bonferroni method, were used to determine differences among means.

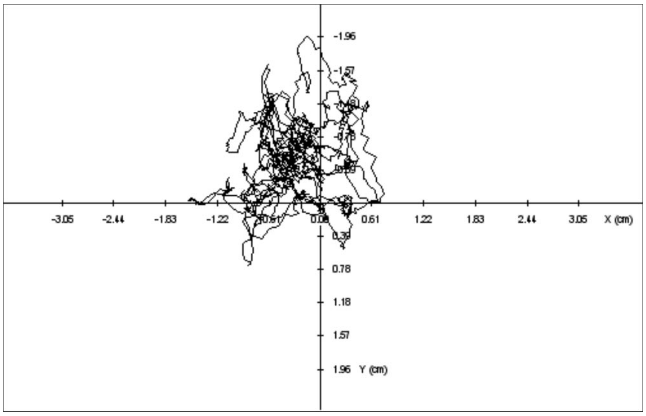

Fig. 1. Plot of the path of the center of pressure (COP) during a 30-second trial of standing still. The starting position of the COP is located at the origin of the plot. Movement along the *x*-axis indicates displacement in the medial-lateral direction, and movement along the *y*-axis indicates displacement in the anteroposterior direction.

RESULTS

Each of the repeated- measures ANOVAs performed met the assumption of sphericity ($p > 0.05$). Figure 2 depicts the impact of cognitive task condition on SR. For SR-ML, the ANOVA revealed main effects of the cognitive task condition ($F = 5.33$, $p = 0.009$) and trials ($F = 9.11$, $p = 0.001$). Pairwise comparisons revealed a smaller ML-SR for the counting backward task than for the standing still task, but a greater range for trials 2 and 3 than for trial 1. For SR-AP, the ANOVA revealed an effect of the cognitive task condition ($F = 5.55$, $p = 0.008$), with less AP-SR when counting backward than when simply standing still. There were no effects due to trial for SR-AP.

Figure 3 shows the influence of the cognitive task condition on SV. SV-ML was affected by the cognitive task condition ($F = 10.14$, $p < 0.001$), with the COP position less variable for the counting backward task than for the standing still task. In addition, there was a main effect of trial on SV-ML ($F = 8.13$, $p = 0.001$). Pairwise comparisons revealed more variability for the third trial than for the first. The cognitive task condition also affected SV-AP ($F = 5.91$, $p = 0.006$). Counting backward resulted in a less variable AP COP path than reading aloud and standing still. SV-AP did not differ between trials.

Figure 4 depicts the impact of cognitive task condition on LCOP, which approached significance ($F = 3.00$, $p = 0.06$). The ANOVA on LCOP did not reveal an effect due to trial. For all five dependent measures, no significant cognitive task $\times$ trial interactions were found.

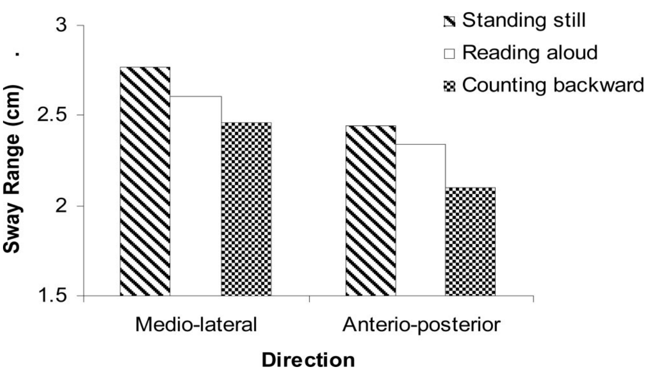

Fig. 2. Sway range as a function of center of pressure movement direction and cognitive task condition.

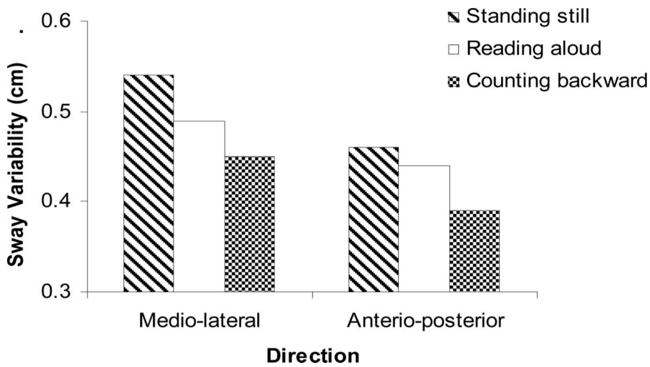

Fig. 3. Sway variability as a function of center of pressure movement direction and cognitive task condition.

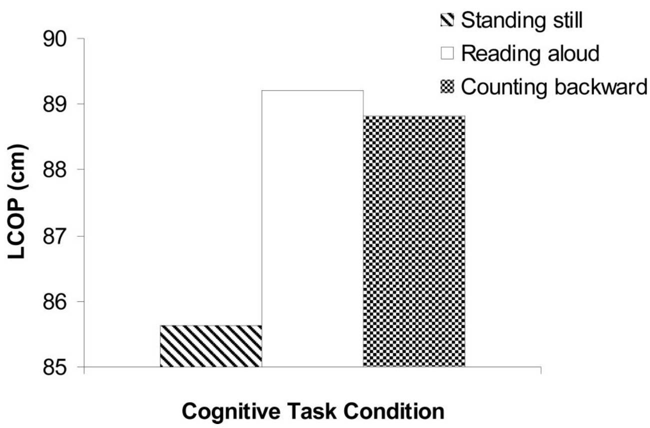

Fig. 4. Length of path of center of pressure (LCOP) as a function of cognitive task condition.

DISCUSSION

Our findings indicate that standing postural stability of fourth-grade children is affected by the attentional demands of concurrent cognitive tasks. The tendency was toward longer COP path length with performance of a concurrent cognitive task (Fig. 4). As this finding is similar to results reported in the adult literature,[7] we were also expecting to find increased SR and SV with increased cognitive demands. Surprisingly, SR (Fig. 2) and SV (Fig. 3) decreased with the added demands of a concurrent cognitive task. Our findings therefore suggest that children may be using a different strategy than adults to adjust their postural sway during concurrent tasks. Children appear to increase their COP path length but do so within a smaller range and with less variability when cognitive demands are added to standing. When confronted with the requirement to perform concurrent cognitive and motor tasks, the children in this study may have limited their SR and SV to simplify the postural task by constraining degrees of freedom.

The changes in postural sway found on repeated trials regardless of the cognitive task condition suggest a practice effect. What might explain the observed increases in ML-SR and ML-SV with subsequent trials? Once again, these findings may be understood in terms of controlling degrees of freedom.[14] When faced with performing a new task, children may have responded initially by ″freezing″ degrees of freedom, making the task easier to perform. With practice through repeated trials, children may then have released additional degrees of freedom as they became more familiar with the task.

Similar to our results, Riley et al[15] reported decreased SV with cognitive tasks involving short-term memory performed during standing. Adult subjects were shown a string of digits for 10 seconds followed by a period of 30 seconds during which they rehearsed the previously displayed digits with eyes closed, thereby eliminating the visual system in the control of posture. Although it is difficult to ascertain the difference in difficulty between the tasks used by Riley et al.[15] and Pellecchia,[7] one could postulate that the elimination of vision in the Riley et al study made the tasks more difficult than the tasks used by Pellecchia. In response to increased task difficulty, adults used a different strategy to maintain stable upright standing as shown by the decrease in SV. This viewpoint may help us better understand our results. Children are still developing strategies in their motor skills to accommodate novel everyday conditions. In controlling posture when confronted with new task requirements, children may initially use a strategy similar to one used by adults during tasks demanding a great level of attention. With practice, the attentional demands of a given task may lessen and children might change their postural strategy to that reported by Pellecchia.[7] Considered collectively, our findings and those of Pellecchia and Riley et al. are consistent with the emerging postulate that postural control is not a reflexive, automatic behavior.[9]

Longitudinal research using dual-task methodology could advance our understanding of the adaptive nature of children's postural control under changing tasks requirements. One challenge in designing these future studies will be to identify cognitive tasks that reflect varying degrees of difficulty and that children are capable of completing. A substantial number of children recruited for the present study had difficulty performing the required tasks as instructed. Specifically, data from 15 of the 35 children recruited for the study were excluded, in most cases, because the children nodded their head or shrugged their shoulders during the reading aloud and counting backward tasks. We observed that, when counting backward, some children had a tendency to nod their head in time with each number count. Directions were read and explained again, but we were not effective in preventing those artifacts in a number of children. It is important to note that the children were able to read the second-grade level sentences and count backward. What was difficult for them was to do these tasks without moving their body. The accompanying body movements may demonstrate the interrelationship between cognition and movement control in children.

Despite study limitations, our research has implications for physical therapists that develop interventions for children. We suggest that therapists should take into account the role that concurrent cognitive tasks play in the performance of simple motor skills such as standing. The conventional approach to pediatric physical therapy has been to focus on the remediation of a motor dysfunction with little consideration given to the dual-task nature of everyday activities. For example, in the clinical setting the pediatric therapist working with a child to improve standing balance might progress the difficulty of the training by adding another motor task, such as catching or throwing a ball. A child's daily routine in the school environment will often require performing motor and cognitive tasks simultaneously. For example, a child may be asked to stand in the classroom and read a story or solve a math problem. Huang and Mercer[10] suggest that differences in perceptual, attentional, and cognitive demands of different settings may contribute to the lack of generalization of effects across settings. It appears from this suggestion and our findings that therapists should incorporate more opportunities to practice dual tasks in the clinical setting to better prepare children to adequately respond and adapt to their everyday environments.

CONCLUSIONS

More questions than answers remain in this new field of research with children. Much is suggested by the findings of our study, but without replication with a larger sample and longitudinal study, this work remains speculative. Our methodology, however, does allow us to conclude that concurrent cognitive tasks while standing do affect postural sway in children. It appears that children adapt their postural stability under conditions of increased attentional demands by reducing SR and SV. It is postulated that, with practice and maturation, children develop different strategies for postural stability to accommodate the changing levels of attentional demands in a given task. A better understanding of the development of postural control under concurrent conditions in the child that is typically developing will lead to improved rehabilitative strategies for children with neurological dysfunction who have altered sensory, motor, and perceptual systems.

ACKNOWLEDGMENTS

We thank the following people from the University of Hartford Magnet School who made this project possible: Patti Mascetti, Beth Phelps, Dr. Cheryl Kloczko, students who participated in the study and their parents, faculty, and staff. We also thank Dr. Diane Ullman from the Capitol Region Education Council in Hartford for her support.

References

1. Pollock AS, Durward BR, Rowe PJ, et al. What is balance? *Clin Rehab.* 2000;14:402–408.
2. Nashner LM. Adapting reflexes controlling the human posture. *Exp Brain Res.* 1976;26:59–72.
3. Shumway-Cook A, Woollacott MH. The growth of stability: postural control from a developmental perspective. *J Mot Behav.* 1985;17:131–147.
4. Massion J. Movement, posture and equilibrium: interaction and coordination. *Prog Neurobiol.* 1992;38:35–56.
5. Hatzitaki V, Zisi V, Kollias I, et al. Perceptual-motor contributions to static and dynamic balance control in children. *J Mot Behav.* 2002;34:161–170.
6. Magill RA . *Motor Learning: Concepts and Applications.* Boston: McGraw-Hill; 1998.
7. Pellecchia GL. Postural sway increases with attentional demands of concurrent cognitive task. *Gait Posture.* 2003;18:29–34.
8. Shumway-Cook A Woollacott MH . Attentional demands and postural control: the effect of sensory context. *J Gerontol Med Sci.* 2000;55A:M10–M16.
9. Woollacott M, Shumway-Cook A. Attention and the control of posture and gait: a review of an emerging area of research. *Gait Posture.* 2002;16:1–14.
10. Huang HJ, Mercer VS. Dual-task methodology: applications in studies of cognitive and motor performance in adults and children. *Pediatr Phys Ther* 2001;13:133–140.
11. Neumann O . Beyond capacity: a functional view of attention. In: Heuer H Sanders AF , eds. *Perspectives on Perception and Action.* Hillsdale, NJ: Erlbaum, 1987:361–394.
12. Allport A . Visual attention. In: Posner MI, ed. *Foundations of Cognitive Science.* Cambridge, MA: MIT Press; 1989:632–682.
13. Lebiedowska MK, Syczewska M. Invariant sway properties in children. *Gait Posture.* 2000;12:200–204.
14. Shumway-Cook A Woollacott MH . *Motor Control: Theory and Applications.* Philadelphia: Lippincott, Williams & Wilkins; 2000.
15. Riley MA, Baker AA, Schmit JM. Inverse relation between postural variability and difficulty of a concurrent short-term memory task. *Brain Res Bull.* 2003;62:191–195.