Background: Balance of the children is greatly compromised in dual-task conditions. In our daily life we perform many dual-tasks. Children with cerebral palsy have difficulty in performing even single-task. To what extent dual-task affects their balance is still not explored widely.

Objective: To identify whether dual-task conditions affect the postural control of children with spastic diplegic cerebral palsy (SDCP) in order to better address the rehabilitation needs and prevent falls.

Materials and Methods: 83 children (45 children with SDCP and 38 typically developing children) in the age group between 8 and 17 years, participated in this cross-sectional study. Single and dual tasks like standing and serial subtraction in standing postures were administered to the child. Postural sway during single and dual-task conditions was recorded by static posturography.

Results: Median sway velocity moment of the postural sway for single and dual tasks was 70.3 mm²/s and 156 mm²/s for the children with SDCP (p<0.001). For children with typical development it were 23.4 mm²/s and 61.8 mm²/s respectively (p<0.001).

Conclusion: Postural sway is significantly increased in both single and dual-task condition in children with SDCP compared to typically developing children.

Clinical trial registration number: CTRI/2011/04/001678

Keywords: Postural balance, Spastic diplegic cerebral palsy, Posturography, Cognitive task.
INTRODUCTION

Balance problems are common and affect functional mobility in children with Spastic Diplegic Cerebral Palsy (SDCP). The body’s position in space is controlled for dual purposes of stability and orientation by Postural control. The postural dysfunction in cerebral palsy is due to the decreased capacity to modulate postural activity in certain situations. Recently researchers have suggested that postural control requires significant attention. The attentional demands of maintaining an upright posture have been demonstrated by researchers using the dual-task paradigm and postural control task have been chosen by them as primary task. Dual-task conditions is a situation in which a person performs two attention demanding tasks simultaneously. Most of our environments are blended with background noise, obstacles, and distracting visual and auditory stimuli. In our daily life with or without our attention we perform dual-tasks.

Typically developing children (TDC) are capable of dividing the attention between the tasks within the limit such that neither of the tasks is affected. Dual-task interference occurs due to the conflict arising in resolving the allocation of attention between two tasks. Kerr and colleagues performed the first research to demonstrate attentional demands of postural control in stance. Pellecchia reported that attentional demands of concurrent cognitive task increases the postural sway. Blanchard along with Pellecchia were first to demonstrate the interaction between the cognitive process and motor control in pediatric population. Various studies have shown the combined effects of physical and cognitive tasks on postural sway in both adults and children with SDCP.

Recently there have been an increasing number of studies showing the attentional requirements in young and older children during postural tasks and in various neurological conditions. But there is a dearth of literature in examining the postural sway during the attentional demands of a concurrent cognitive task in children with cerebral palsy. The study done by Dinah et al showed children with cerebral palsy were more unstable and had experienced the interference of dual-task in postural control during standing when compared with older children, and the typically developing young children. But the level of task difficulty was not equal between the groups of children with cerebral palsy and the children with typical development. Thus increase in postural sway recorded between single and dual-task conditions might be due the difference in load of the unequal distributions of cognitive dual task.

Most of the children with SDCP are ambulant. They often encounter numerous dual-task situations in their daily living activities. Therefore there is a need of study to identify whether dual-task conditions affect the postural control of children with SDCP to pinpoint the importance of the rehabilitation needs and to decrease risk of falls. The purpose of the study is to compare the postural sway between the children with typical development and children with SDCP during single and dual-task conditions.

MATERIALS AND METHODS

The study was approved by the research committee of Manipal College of Allied health sciences and the ethical clearance (reference No. UEC/13/2010) was obtained from ethics committee of Manipal University. The study protocol has been registered in The Clinical Trials Registry of India (CTRI), registration No. CTRI/2011/04/001678. Consent forms were signed by parent or their legal guardians, after an explanation of the test procedures and assent of the child were also obtained prior to beginning the data collection. The cross-sectional study was conducted according to the ethical standards of the Helsinki Declaration (Revised 2000).

Subject’s recruitment

A total of 83 children, ranging between 8 and 17 years, participated in the study. Out of the 83 children, 45 were diagnosed with SDCP and remaining 38 were children with typical development. Children with SDCP were recruited from the department of physiotherapy, Kasturba Hospital, Manipal. Anthropometric measurements of height and weight were recorded for all subjects. The children with SDCP of functional mobility with Gross Motor Function Classification System (GMFCS) I, and
II and who were able to maintain static stance for 30 seconds without assistance were recruited. Children, who were, uncooperative, with hearing deficit, inability to articulate numbers and less than 6 month post orthopedic surgery or post botulinum toxin injections, were excluded from the study. The study was conducted in the Balance rehabilitation Unit, department of physiotherapy, Kasturba Hospital, Manipal.

Posturography

We used the commercially available computer-based system (Good Balance ™, Metitur Ltd, Jyvaskyla, Finland) for the force platform tests. The system consists of an equilateral triangular force platform (width 800 mm, height 70 mm, with strain gauge transducers at each corner of the platform), a three-channel DC amplifier, an eight channel 12-byte analogue-to-digital converter (sampling frequency 50 Hz) and a computer program installed in a desktop PC (Windows XP-operating system). The calibration of the force platforms was checked regularly weekly and before each day start of measuring the postural sway. Using the force platform, postural sway was tested in single-task and dual-task conditions.

Cognitive level equating

Postural control task was selected as the primary task and we used cognitive task as the dual-task. To estimate the individualized cognitive dual-task, we adopted the method of serial subtraction. The child was made to sit comfortably in chair and they were asked to serially subtract 1 from 100. If they were able to perform this, then the difficulty of the cognitive dual-task was progressively increased till they committed 30% error in a particular series. The particular series was the cognitive dual-task for them. This was done to equate the attentional load level of cognitive task to 70% between groups. Thus the variable dual-task interference due to the differential workloads of the cognitive task between groups was eliminated.

Procedure

After estimation of the individualized cognitive dual-task, postural sway in single and dual-task were recorded. The child was asked to stand in the force platform of the posturography in their comfortable stance with hands crossed across their body. This was done to minimize the postural sway interference due to relaxed hanging positions of hands. As there was the risk associated with falls, a therapist was made to stand behind the children for the safety concerns (Figure 1). The subjects were instructed to remain still in their position and not to move while focusing a black spot three feet away for 30 s. The postural sway in their single-task was recorded.

During the rest between trails, the child was made to sit on the plastic chair placed on wooden base of platform but care was taken not to alter the BOS. After adequate rest the subjects were instructed as above to stand still and asked to serially subtract beginning at number 50. This was done to prevent the learning effect while estimating dual-task in relaxed sitting position.

Table 1 Demographic Characteristics

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>CSDCP (n = 45)</th>
<th>TDC (n = 36)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male : Female</td>
<td>25:20</td>
<td>14:22</td>
</tr>
<tr>
<td>Age in years (mean ± SD)</td>
<td>11.11 ± 2.49</td>
<td>10.26 ± 2.05</td>
</tr>
<tr>
<td>Height in cm (mean ± SD)</td>
<td>132.99 ± 13.13</td>
<td>133.13 ± 13.38</td>
</tr>
<tr>
<td>Weight in kg (mean ± SD)</td>
<td>29.93 ± 10.46</td>
<td>30.71 ± 9.41</td>
</tr>
</tbody>
</table>

CSDCP - Children with spastic diplegic cerebral Palsy, TDC - Typically developing children.

Figure 1 Recording of the Postural sway
The subjects were strictly instructed not to nod their head while serially subtracting. By the similar above procedure the postural sway in dual-task conditions were recorded. The subjects were asked to start subtract 2-3 s before recording the postural sway by posturography and to stop 2-3 s after recording the postural sway. The data recorded were stored for analysis.

**Statistical Analysis**

All the statistical analyses were performed using the statistical package for social sciences (SPSS, version 17.0 Inc., Chicago, IL) for windows 7 ultimate edition. Normal Gaussian distribution of the data was verified by the Shapiro-wilk’s test. Because none of the variables met normal distribution, we opted for a nonparametric procedure. Descriptive statistics were presented as mean ± SD for collected the data. Wilcoxon Signed Rank test of significance was used to find within group difference of postural sway in single and dual-task between children with typical development and children with SDCP. Mann-Whitney U test of significance was used between group differences in postural sway in single and dual-task. P values less than 0.05 was considered to be statistically significant.

**RESULTS**

The demographic characteristic of the subjects included in both groups with mean ± SD values for age, height and weight are given in Table 1.

The children with SDCP were distributed in either GMFCS I, and II. There are 28 (62%) children with SDCP were in GMFCS I while 17 (38%) are in GMFCS II. Figure 2 shows the median sway velocity in the anterioposterior (AP) direction in children with TDC and children with SDCP. Wilcoxon Signed Rank Test showed significant difference of p < 0.001 between single and dual-task in both the groups. Mann-Whitney U test revealed that there was a significant difference of p < 0.001 and p = 0.001 between the groups in single and dual task conditions respectively.

Figure 3 shows the median sway velocity in the mediolateral (ML) direction in TDC and in children with SDCP in their single and dual-task conditions. Wilcoxon Signed Rank Test showed significant difference of p < 0.001 between single and dual-task in both the groups. Mann-Whitney U test revealed that there was a significant difference of p < 0.001 and p = 0.001 between the groups in single and dual task conditions respectively.

**DISCUSSION**

The purpose of the study was to explore the effect of dual-task conditions on postural control in children with SDCP and TDC. We classified our samples according to the functional ability using GMFCS and we had 28 (62%) and 17 (38%) children with spastic diplegic under GMFCS I and II respectively. In estimating cognitive dual-task, the attention load level equating was pre-set as 70% accuracy for both the children with SDCP and their children with typical developments. This was set in similar manner as done by Vogel et al.\textsuperscript{14} and Dinah et al.\textsuperscript{12} The learning effect was minimized during the sway measurement by asking the child to recite backwards the numbers which was not used in titrating the appropriate cognitive dual-task to the children.

Frequent change in focus of the child was tried to minimize, by giving repeated auditory cues. Even after 3 trials the child was not able to focus a particular target then the child was excluded from the study. By this 8 children with SDCP were excluded from the study. Dual-task interference due to error in visual acuity, was minimized by made the child to wear the spectacle if they have been prescribed and then to focus the target. Change in BOS (Base of Support) between trails of single and dual-task were avoided to eliminate the discrepancy in postural sway due to variation in BOS. As the extra postural sway due to articulatory effect results in lesser than 0.3 mm random error along
both AP and ML directions which was reported by Donker et al. as negligible, this was not taken into consideration.

Drift velocity in postural sway can be created by sudden initiation in articulating numbers during the posturography recording. This was eliminated by making the children to articulate numbers in reverse order 2-3s before recording the postural sway by posturography. In similar instance, he was asked to stop articulating numbers 2-3s after recording of postural sway. By this the drift variance in postural sway was minimized. The children were asked to cross their hands across the body to overcome the sway recorded due to the swinging of the arm by the side. Dual-task was focused only to cognitive task in this study. The child was asked to remain in their comfortable stance position as this would be of more functional stance position in real life situation. This would

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**Figure 2** Comparison of the median postural velocity (mm/s) in AP direction between single and dual task conditions in TDC (Typically Developing Children) and children with SDCP (Spastic Diplegic Cerebral Palsy)

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**Figure 3** Comparison of the median postural velocity (mm/s) in ML direction between single and dual task conditions in TDC (Typically Developing Children) and children with SDCP (Spastic Diplegic Cerebral Palsy)
help us to understand to what extent the child sways in dual-task conditions in real life situations.

Our study has confirmed that children with cerebral palsy and their TDC experienced a decrement in posture stability in performance of the secondary cognitive task (p < 0.001 and p = 0.001 respectively). With the introduction of the dual-task condition, both the groups had a significant increase in their AP and ML postural sway. Those children with SDCP experienced greater sway velocity when compared to their TDC. We noted a significant increase in postural sway in dual-task condition in TDC as observed by Blanchard et al\textsuperscript{11} and this might due to the normal division of attention when two tasks were introduced but they were able to maintain within their stability limits. The children with cerebral palsy, having impairments in both the postural control and executive attention network systems, have postural control interference in dual-task conditions, greater to their TDC. This might be due to impairments in the neuromuscular, sensory integrative and musculoskeletal systems in children with SDCP. The findings are line with the study done by Dinah et al\textsuperscript{12}

The children with SDCP were more unstable even in their single-task both in AP and ML directions. These sway velocity were higher than that of their TDC (14.5 mm/s & 12.5 mm/s – single-task of spastic diplegic cerebral palsy to 14 mm/s & 10.5 mm/s – dual-task in TDC). When dual-task condition was introduced the children with SDCP become more unstable. Velocity moment of postural sway between single and dual-task conditions in children with SDCP & children with typical developments were significant of p <0.001. By comparing the VM of dual-task of TDC (70.3 mm\textsuperscript{2}/s) and to VM of single-task of the children with SDCP (63.8 mm\textsuperscript{2}/s), we could interpret that how much they differ in single task conditions.

The increase in postural sway might due to conflict in resolving allocation of executive attention between two simultaneous tasks. Christ et al showed that children with SDCP experienced deficits in their ability to inhibit irrelevant stimuli when performing a task.\textsuperscript{16} Children with SDCP sustain prefrontal cortex lesions in their white matter connecting with other brain regions.\textsuperscript{17} Neurophysiologic studies have shown that these areas are required for allocation of attention.

Even though the exact location of the cerebral lesion in our sample of children with SDCP is unknown, it is possible that the area responsible for the allocation of attention, the dorsolateral prefrontal cortex and the dorsal anterior cingulate gyrus is involved. As postural sway velocity in dual-task conditions in TDC (Typically Developing Children) and children with SDCP (Spastic Diplegic Cerebral Palsy).

\begin{figure}
\centering
\includegraphics[width=\textwidth]{figure4.png}
\caption{Comparison of the median velocity moment (mm\textsuperscript{2}/s) between single and dual task conditions in TDC (Typically Developing Children) and children with SDCP (Spastic Diplegic Cerebral Palsy).}
\end{figure}
Postural Sway in Dual-task Conditions

sway increases, the stability decreases. There is increased risk of fall among the children with SDCP. Especially when administering dual-task to these children care should be taken due to high instability in dual-task conditions. The limitations of the study were that the sway represented during static standing in laboratory conditions may not represent the sway during functional tasks. We further recommends studies incorporating dual-task in other functional activities in the children with SDCP and dual-task training for improving the balance in children with SDCP could be drafted. This study implies the importance to educate the children and the parent about the risk of fall during dual-task conditions and to incorporate similar training situations.

CONCLUSION

Postural sway is significantly increased in anterioposterior and mediolateral directions of both single and dual-task condition in children with SDCP compared to their TDC. Children with SDCP might undergo dual-task interference due to discrepancy in allocation of attention.

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CONFLICTS OF INTEREST

None declared

REFERENCES