Static Balance Performance and Sensory Integration Abilities of Children with Dyslexia and Developmental Coordination Disorder

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Abstract: **Introduction:** Postural dysfunctions are described in Developmental Disorders: the static balance deficit is one of the major features of Developmental Coordination Disorder (DCD) and is reported in Dyslexic Children. With computerized dynamic posturography (CDP) balance can be assessed objectively. The primary aim of this study was to assess the postural function in DCD and Dyslexic in comparison with a Control Group (CG) using CDP.

Subjects and Methods: Forty-seven children (29 males e 18 females) were assessed using all the six conditions of the Sensory Organizing Test (SOT). 18 CG children (mean age 9.66 ± 1.96 years), 15 Dyslexic children (mean age 9.78 ± 1.09 years) and 14 DCD children (mean age 8.35 ± 1.79 years) were included.

Results: DCD had poorer balance measured with the SOT score in every condition ($p<0.05$) except in SOT 3 (p= n.s.) compared to the CG. Dyslexic children had a good postural control compared to the CG, except in SOT 5 ($p = 0.02$).

Conclusions: CDP showed that the DCD group had, as expected, a poorer balance than DD and CG. It is possible to differentiate Dyslexics from the CG only in SOT 5, indicating that the postural disturbance of this group is probably of primarily central vestibular origin. The somatic-sensory input had the same influence on balance function in the three groups.

1 INTRODUCTION

The sensory integration is a physiological process in selecting and combining appropriate sensory information from somatosensory, visual and vestibular systems. The Sensory Organization Test (SOT) of the Computerized Dynamic Posturography (CDP), is an objective measure of sensory integration during balance performances. SOT evidences more data and information than clinical tests, using an objective analysis of balance function (Nashner, 1997).

SOT analysis can help to identify the cause of instability and the patient's balance strategies (Nashner, 1997; Prieto et al., 1996). But few studies adopt CDP on Developmental Disorders in children. Balance problems are described in children with Developmental Dyslexia (DD) and Developmental Coordination Disorder (DCD): whereas balance impairment is a common feature and a "core" symptom in DCD (Fong and Tsang, 2012), few studies have investigated whether deficits in multisensory integration may contribute to poor standing balance in children with DCD (Deconinck et al., 2008). Geuze (2005) claims that under normal conditions, static balance control is not a problem for these children. For the majority of them, this problem seems not to be due to greater dependence on vision.

Moreover experimental studies resulted in the general conclusion that DCD children had deficits in standing balance control in conditions that included reduced (in particular visual and vestibular) or conflicting sensory signals (Fong and Tsang, 2012), showing more postural sway in either one-legged (Geuze, 2005) or two-legged stance (Przysucha and Taylor, 2004). Converging evidence indicates that cerebellar dysfunction contributes to the motor problems of children with DCD. Objective measurements confirmed these results evidencing, in

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a small sample of DCD, an altered pattern in the SOT (Inder and Sullivan, 2005).

Literature on balance control in DD is inconclusive: motor performance difficulties in DD are attributed to a disorder in visual processing (Stein and Walsh, 1997), in rapid information processing (Tallal et al., 1993), and some studies reported a postural control impairment and a cerebellar deficit (Fawcett and Nicolson, 1999). Nicolson et al. (1999), reported motor coordination and balance deficits in dyslexic children population. Other authors suggested that the balance impairment was not strictly correlated with dyslexia but also with other types of developmental disorders (such as comorbidity with Attention Deficit/Hyperactivity Disorder (ADHD) (Raberger and Wimmer, 2003).

These opposite findings in the literature on the argument could be influenced by differences in the assessing processes: the use of different tasks in evaluating balance, such as measuring the balance only on the right or left foot (Stoodley et al., 2005), the use of subjective measures of postural control (Fawcett and Nicolson, 1999) and the evaluation of dyslexic children only in the "eyes open" condition (Moe-Nilsen et al. 2003).

The aim of this study was to assess postural control of a DCD sample through the objective measure of CDP, and to compare their balance performances with DD children without co morbid attention deficits and with a matched CG.

2 METHODS

Forty-seven children participated in the study. All participants demonstrated adequate familial environment, middle socio-economic status and Wechsler Intelligence Scale for Children Revised over 90. No child had attention-deficit disorder, epilepsy, mental retardation, cerebral palsy, psychiatric disorders, or other neurological signs, congenital malformations, or phoniatric alterations, neither peripheral vestibular disorder and inner ear disease as referred by the anamnesis and the clinical evaluation. Subjects were divided in three groups: a control group (CG) of 18 children (mean age 9.66 ± 1.96 years), a group of 15 dyslexic children (DD) (mean age 9.78 ± 1.09 years) and a group of 14 DCD children (mean age 8.35 ± 1.79 years). The diagnosis of DD and DCD was done according to DSM-IV criteria. Children included in the DCD group scored below the 15th percentile on the total impairment score on the Movement-ABC standardized test. Written informed consent to participate in the study was obtained by parents of all children. The study was approved by the IRCSS San Raffaele, Hospital of Rome Pisana, Institutional Internal Review Board. Postural control function was assessed by SMART EquiTest 8.0 (NeuroCom Int., Inc., Clackamas, OR, USA) instrument, using static and dynamic CDP. This instrument has been adopted as the only method to isolate the functional contributions of vestibular inputs, visual inputs, somato-sensory inputs, central integrating mechanisms, and neuromuscular system outputs for postural and balance control (Black, 2001) and the instrument meets the testing standard for CDP set by the American Academy of Otolaryngology-Head and Neck Surgery and the American Academy of Neurology. All subjects were evaluated using the Sensory Organization Test (SOT) of Dynamic Posturography (Equitest© Neurocom). The SOT analyses the postural control and the contributions of different sensory systems to balance control during 6 conditions, each test condition was examined three times for 20 seconds with a 20-second break between tests. Six different conditions (A-F) were used in order to examine the subject's balance control performance under different sensory conditions that we will call C1, C2, C3, C4, C5, C6 (Table 1, Table 2).

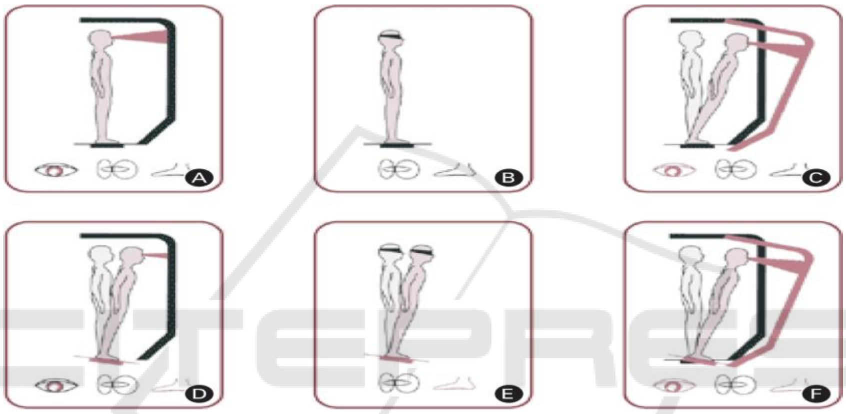
The force plate and visual surround are "sway referenced" so that they can move to follow the anterior-posterior sway of the subject. The six conditions of the SOT are called Equilibrium Scores (ES), that are obtained by comparing the maximum anterior-posterior CoG displacements to a theoretical maximum displacement. The ES ranges between 0 and 100. Lower ES indicate increased body sway peak-to-peak amplitudes. The score of "0" was recorded if the subject falls, touches, or gripes reference for protecting. Nobody sway results in a perfect score of "100." The Composite Equilibrium Score (CS) is a synthetic index of equilibrium and is a mean value from the scores of all six conditions. The CS is evaluated as a weighted average of one subject's equilibrium scores from six conditions of the SOT: $CS=\{ES(1)+ ES(2) +3[ES(3)+ ES(4) +ES(5)+ ES(6)]\}/14$.

Statistical Analysis. We used one-way ANOVA to evaluate differences between groups in mean Composite Score, Condition Scores and in Sensory Analysis Scores. We performed the multiple comparison of the means using the post-hoc Tukey-Kramer test. Pearson correlation coefficients were used to analyze the relationship between age and Condition Scores. Reported results are considered significant for $p < 0.05$.

Table 1: Sensory input conditions during SOT.

Sensory condition description	Accurate Sensory	Sensory loss	Sensory conflict
C1. (A) Eyes open, fixed support	Visual, vestibular, somatosensory	None	None
C2. (B) Eyes closed, fixed support	Vestibular, somatosensory	Visual	None
C3. (C) Eyes open, sway-referenced visual surround	Vestibular, somatosensory	None	Visual
C4.(D) Eyes open, sway-referenced platform	Visual, vestibular	None	Somatosensory
C5. (E) Eyes closed, sway-referenced platform	Vestibular	Visual	Somatosensory
C6.(F) Eyes open, sway-referenced visual surround and platform	Vestibular	None	Visual, somatosensory

Table 2: Six conditions (A–F) of SOT.



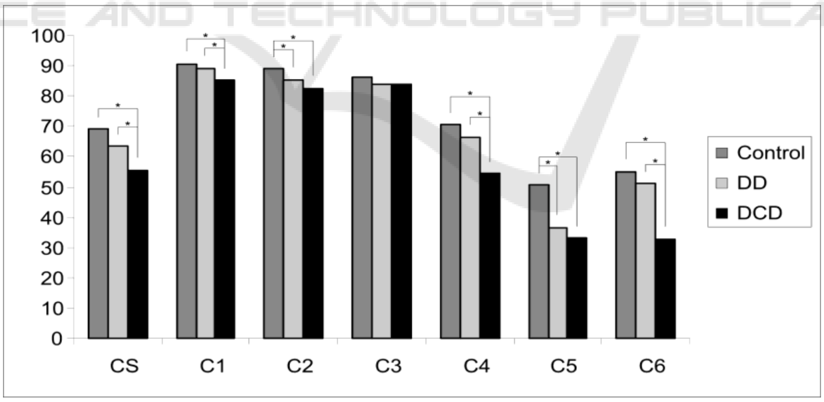


Figure 1: Composite Score and Condition Scores. Average (+SD) composite and condition scores across different groups (Control: control group, DD: children with Developmental Dyslexia, DCD: children with Developmental Coordination Disorder). Asterisks denote significant (Tukey-Kramer post-hoc test $p < 0.05$) differences.

3 RESULTS

The data showed significant differences in the results of SOT among groups (p-value < .001) (Fig.1); the 40% of DD children and 93% of DCD children had a lower CS, than the mean value of CG. The results of our CG were similar to that reported in literature (Steindl et al., 2006).

The DD group had scores similar to control values in all conditions, except for condition 5.

The mean C5 score of DD was similar to the mean C5 score of DCD group and was significantly

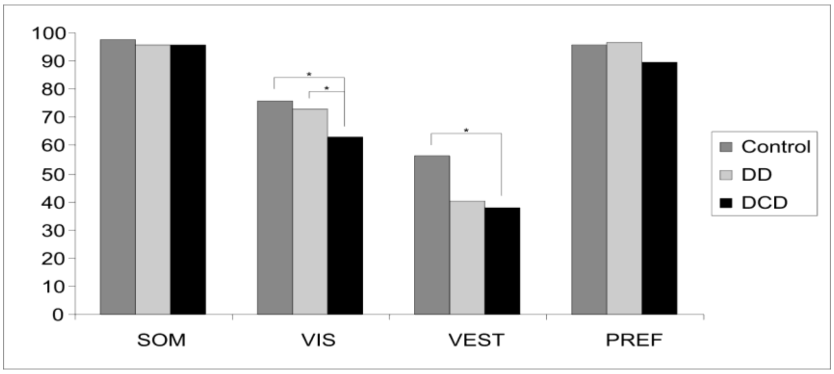


Figure 2: Sensory Analysis of Control group, DD and DCD groups. Asterisks denote significant (Tukey-Kramer post-hoc test p < 0.05) differences.

poorer than control group (p-value = .020). Furthermore, 53% of DD children had a lower score in condition 5 than control children. The DCD children had significantly worse results than the other two groups in all conditions (p-value < .05) except for Condition 3. In this condition there were no significant differences among groups (p-value = .524)

Moreover, 71% of DCD children had a lower score in condition 5 than control group. Correlations between age and condition scores were not found (Pearson correlation coefficient < .60). The results of sensory analysis showed that the somato-sensory input had the same influence on balance function in the three groups. Nevertheless in the DCD children the use of visual and vestibular information in maintaining balance was significantly less efficient than controls. The DD children had a similar result to DCD group for the vestibular afference, but a normal use of visual information in maintaining equilibrium (Fig.2).

4 DISCUSSION

Our results showed balance performances and different sensorial patterns in two different groups of children with Developmental Disorders. The strategies of DD and DCD groups, during balance tasks, were different from those adopted by CG. We found a significantly lower balance control of DCD group than other groups in upright standing condition (condition 1 and condition 2), even if their poorer performances were in tasks with sway-platform (condition 4, condition 5 and condition 6). These findings are consistent with previous literature reporting a larger dependency of DCD children on vision and difficulties in integrating visual and non-visual information (Wann et al., 1998). Our DCD children perceived a sway visual surround as a negligible input in maintaining balance, their scores were normal in conditions with visual reference sway (condition 3). This result indicated a normal ability to discriminate a destabilizing visual input, which is a cortical function. Geuze (2005) found that an improvement in conflicting sensory inputs can occur with eyes open. It seems that the unavailability of an important sensory information such as visual-perception can influence the quality of postural and balance control in DCD Children. Postural control problems may possibly be associated with difficulties to re-weight sensory information in response to environmental demands (Deconinck et al., 2008).

In summary, we observed poorer static postural control ability in children with DCD compared with Controls and the vestibular system failed to effectively integrate sensory information of insufficient and/or inaccurate visual or somato-sensory perception, thus leading to loss balance. However in the visual conflict they could maintain balance (condition 3).

Our DD children showed significant impairment of balance control with increasing task difficulty (i.e., reduction or conflict of sensory inputs) which is consistent with others findings: some motor impairment in relatively complicated balance tasks (dual-tasks) and in presence of conflicting sensory inputs (Huxhold et al., 2006). Balance performances of our sample showed that DD children had a normal composite score. Balance function in DD group was better than DCD group, however in DD children we found higher incidence (53%) of poor balance performances in complex tasks (condition 5). The poor balance performance of DD children in this task is associated with the visual exclusion and to grounding on vestibular information (somato-sensory conflict); DD children had a lower performance with eyes closed. These findings are in contrast with findings from other authors reporting lower balance performances of dyslexic children in eyes open tasks (Moe-Nilssen et al., 2003; Stoodley et al., 2005) or normal postural stability in both conditions (Brown et al., 1985). A possible explanation of these differences can resides in the balancing task proposed by these authors. It is well established that postural stability is task dependent (Cho and Kamen, 1998).

The stance position with eyes open could be too easy for DD children; these tasks may not be able to evidence balance control impairment in patients with a normal somato-sensory and visual afferents. These children in fixed surface with eyes open condition use information from somato-sensory and visual systems to maintain upright position.

Ramus and colleagues, who found evidence of impaired balance control in dyslexic children, related it to an altered vestibular pattern (Ramus et al., 2003). Our data similarly indicated poor vestibulo-spinal postural control.

Several studies evidenced the activity of cerebellum and basal ganglia in sensory-motor integration function and in learning, furthermore, their role is still unclear (Waber et al., 2004).

5 CONCLUSION

In conclusion, this study, in accordance with previous reports, provided evidence suggesting that DCD and Dyslexic children have impaired postural stability compared to children of similar age.

The small sample size is the main limitation of this study and these findings could be explored further with a larger sample. In agreement with the hypothesis of sensori-motor deficit in DD and DCD, these children could suffer of a sensory multimodal integration difficulties.

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