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Motor impairment in children with autistic spectrum disorder and in children with attention deficit hyperactivity disorder

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ABSTRACT

We summarize postural instabilities in children with autistic spectrum disorder (ASD) and in children with attention deficit hyperactivity disorder (ADHD), and we reported behavioral results suggesting poor cerebellar integration. We conclude that postural measures could be a promising method with which to indirectly observe cerebellar performance in children developmental disabilities such as ASD and/or ADHD.

Introduction

Postural control relies upon multiple sources of sensory information from the visual, vestibular, and somatosensory afferents¹. It is also well known that various structures in the central nervous system, such as the basal ganglia, the brainstem, the cerebellum, and several cortical areas are involved in postural control². To reach a postural stability during everyday life in the natural environment subject needs to weigh all these information and a deficit in one of these inputs may lead to an imbalance in other sensory inputs and may lead to postural instability.

In 1992, Kohen-Raz³ and collaborators were the first to record postural stability in children with autistic spectrum disorder (ASD) using a platform and they reported that children with ASD were significantly more unstable than control children. A synthesis and meta-analysis of deficits in motor control in children with ASD was done by⁴ and several other studies⁵⁻¹⁰ observed postural instability in children with ASD. Furthermore, with altered somatosensory inputs (i.e. a sway-reference surface, or standing on foam or wearing a vibrating device around the neck region) children with ASD reported poor postural control with respect to TD children^{3,4,5,12,13,14}.

All these reports are in line with the hypothesis that a deficit in multimodal sensory integration, in other words poor ability to reweight sensory inputs could be at the origin of such motor impairment in children with ASD.

In line with this hypothesis, other researchers proposed an internal

modeling deficit for children with neurodevelopmental disabilities (for instance, in children with Developmental Coordination Disorder as reported from¹⁵. This idea, proposed firstly by¹⁶ Morasso et al. (1999) is based on the hypothesis that internal models allow stability to the body by predicting the movements before that sensori-motor feedbacks are available. Dysfunctions to this mode of motor control could severely affect motor learning capabilities in these patients that it could be most likely due to parieto-cerebellar abnormalities as suggested by¹⁷.

Motor problems occur in 30-50% of children with Attention deficit hyperactivity disorder (ADHD)¹⁸. ADHD is associated with poor gross and fine motor control abilities^{19,20,21} and several studies from our^{22,23} and other groups^{24,25,26} reported postural instability in ADHD children compared to control children. In more details, the velocity of the center of pressure was found significantly higher in children with ADHD than in control children group^{24,25}. Interestingly, postural deficits was found to be even more pronounced when children were tested in more difficult conditions, such as when their eyes were closed and/or by manipulating the visual surround response^{26,27,28}.

A recent study of²⁹ found out, for the first time, a positive correlation between postural sway and cerebellar gray matter volume in adults with ADHD, providing additional support for cerebellar involvement in ADHD.

Note also that as reported by³⁰ in a recent review, cerebellar deficiencies have been found in several developmental disorders (autism, dyslexia, ADHD); She suggested that deficits in different cerebellar subregions related to poor specific cerebro-cerebellar circuits could lead to the behavioral symptoms at both motor and cognitive levels observed in these types of children.

In the present study we wonder to explore further postural capabilities in children with ASD and ADHD and to compare these results with those reported in a group of typically developing children.

Methods

Subjects

Here, we reported a study in which we compared postural capabilities in three different groups of twenty-five children sex-, IQ-and age-matched (mean age: 10.5 ± 0.4 years): *group 1*, children with ASD; *group 2*, children with ADHD and *group 3*, typically developing children by using the Multitest Equilibre, also called Balance Quest, from Framiral® (www.framiral.fr), which permits to analyze the Center of Pressure (CoP) both in the spatial and temporal domains.

Children were enrolled in the study at the Child and Adolescent Psychiatry Department, Robert Debré Hospital

(Paris, France). Their neurological examination was in the normal range and they were naïve of psychotropic treatment. All children examined had the intelligence quotient (IQ) in the normal range (between 85 and 115). The diagnosis of ASD and ADHD was done according to DSM-5 criteria³¹.

Postural recording

The Multitest Equilibre test, from Framiral® records the displacement of the CoP sampled at 40 Hz. Several studies from our^{32,22,23} and other groups^{33,34} used this system to objectively record postural sway.

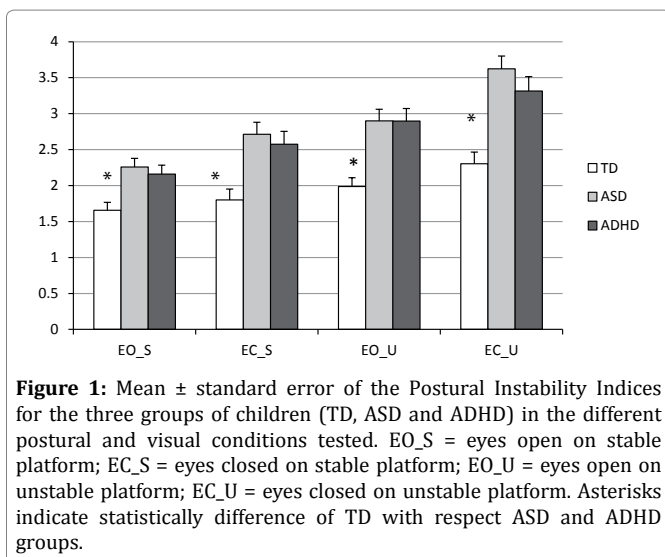
A wavelet non-linear analysis using Morlet waves was applied to CoP displacements in order to elaborate a time-frequency chart of body sways^{33,35}. Such analysis allows revealing temporal fluctuations in the body sway spectrum and the postural instability indices (PII) were measured which quantifies the postural performance by taking into account the spectral power index (PI) and the cancelling time (CT); it was calculated as follows: $PII = \frac{\sum x \sum y}{PI(F1, F2, F3) \cdot CT(F1, F2, F3)}$, where PI and CT are the spectral power index and cancellation time for each of the three frequency bands (F1, low; F2, medium; F3 high frequency band, see³⁶). Note that this parameter is a global postural index used during routine test by clinicians and allowing an easy and quick evaluation of the child's postural instability. The larger is the PII, the greater is the instability.

Procedure

The child was placed on the Framiral® platform in a dark room and he/she was positioned with the feet aligned in parallel on the footprints, and the arms hanging along the body. The postural recording was performed on both a stable (S) and an unstable (U) platform, under two different visual conditions: eyes open (EO) and eyes closed (EC). The child was asked to stay as stable as possible. During the EO condition, child had to fixate a small red light at a distance of 2.5 m. The duration of each postural recording was 30 seconds, with a 15-second rest period between conditions to reduce the possible effects of tiredness. The order of the conditions varied randomly across children.

Results

Figure 1 shows the PII for the different postural and visual conditions for TD, ASD and ADHD children, respectively. ANOVA reported a significant group effect ($F_{(2,72)}=18.67$, $p<2.9 \times 10^{-7}$, $\eta^2=0.34$) a postural and visual condition effect ($F_{(1,72)}=68.91$, $p<5.1 \times 10^{-12}$, $\eta^2=0.49$ and $F_{(1,72)}=31.69$, $p<3.2 \times 10^{-7}$, $\eta^2=0.31$) respectively). Interestingly, the PII was significantly larger in ASD and ADHD children with respect to TD children, but these values were similar in the two groups of children with ASD and with ADHD.



Discussion

As reported by the PII measures, children with ASD and children with ADHD show a similar instability and a common postural pattern: the Postural Instability Indices are larger, particularly when vision is not present on an unstable platform with respect to those observed in TD children. Note also that, in contrast to Sjöwall’s report³⁷, given the small variability of the data observed in our patients, postural control was poor in all children examined.

Such body instability reported in children with neurodevelopmental disorders could be due to their impairment to use adaptive mechanisms to compensate/reweigh sensorial inputs as hypothesized by³⁸ this deficit is more pronounced when children are tested in difficult conditions (for instance, when eyes are closed and when the platform is unstable). Indeed, it is well known that healthy children are more instable in a such conditions, most likely due to their difficulty to compensate with other sensorial inputs see³². We advanced the hypothesis that such difficulty could be more important in children with neurodevelopmental disorders than in TD children.

Recall that the cerebellum is involved in motor learning and motor control, and patients with cerebellar tumors showed large instability with respect to healthy subjects, particularly in deprived sensory conditions^{39,26}. It has also been reported that cerebellar activity increased during standing posture^{40,41} and a recent study by⁴², using a transcranial direct current stimulation applied over the cerebellum, also showed a direct effect of the cerebellum on postural control. Based on these findings and Stoodley’s report (2016) previously cited, we suggest that the poor postural control observed in children with autism and hyperactivity could be due to cerebellar impairment and deficiencies in cerebrocortical network, leading to abnormal instability. On the other hand we could not

exclude that other parts of the brain (as basal ganglia, brain stem, cortical areas), and sensory nerves are also deficient in these patients.

⁴³suggested that postural abnormalities in children with neurodevelopmental disorders could result from impaired cortico-striatal loops and/or cortico-cerebellar loops more than cerebellar structural abnormalities. We agree with this hypothesis and in order to definitely establish the location of the deficit further imaging studies during postural tasks in children with neurodevelopmental disorders are needed. Interestingly, a recent study of⁴⁴ in children with ADHD reported a deficit in postural sway that was correlated to a decreased brain connectivity from the cerebellum to the premotor and the anterior cingulate cortex.

It is also well known that the cerebellum is under adaptive mechanisms and few studies in patients exist showing cerebellar plasticity after postural training.⁴⁵ observed that in 20 patients with cerebellar degeneration, two weeks of sensorimotor training lead to both an improvement in postural performances and an increase of gray matter volume in the cerebellum and in dorsal premotor cortex; in a group of patients with Parkinson’s disease,⁴⁶ reported a change of grey matter in the right cerebellum, together with an improvement in postural stability after postural training on movable support. Recently,⁴⁷ examined the effect of eight weeks of balance training program in a group of 29 children with traumatic brain injury and they found that the changes in balance control were associated with alterations in the cerebellar white matter microstructure. Future research on postural training in children with neurodevelopmental disorders combined with imaging studies for measuring the cortico-cerebellar activity could be useful to gain more insight on such issue.

Finally, as shown here, we believe that postural measures could be a promising objective method with which to indirectly observe cerebellar performance in children with neurodevelopmental disorders.

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