Behavioral Assessment of Cerebellar Function in Preschool Children Diagnosed With Autism Spectrum Disorder

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Abstract
A large body of literature, including preclinical histopathology, genetic and neuroimaging studies has established the involvement of the cerebellar circuits in the physiopathology of Autism Spectrum Disorder (ASD). The aim of the present study was to assess at a behavioral level the cerebellar function of preschool children aged 4 to 6 years old with ASD, in comparison to a group of age-matched typically developing (TD) children. Seven clinical tests were administered to measure performance into three main areas of cerebellar function: maintenance of posture, hypotonia (reduced muscle tone), and complex movements. Our results showed that children with ASD performed significantly lower in 6 out of 7 cerebellar tests compared to TD children. These findings indicate that cerebellar-dependent motor behaviours are compromised in preschool children with a diagnosis of ASD. Our findings are consistent with previous studies supporting a general cerebellar dysfunction in children with ASD and indicate that these impairments can emerge and be detected as early as at the preschool period of development.

Keywords: Cerebellar Function, Autism, Motor Behavior

Introduction

The cerebellum is a large and highly sinuous structure of the nervous system consisting of two hemispheres, which are connected by a narrower fate, the vermis. Having reciprocal connections with different regions of the cerebral cortex, provides the substrate for cerebro-cerebellar communication about various behaviours (Schmahmann, 2001). Traditionally, it is regarded as the regulator of motor function, occupying a central role in movement coordination. However, in addition to its role as a motor area, more recent studies show that the cerebellum is also involved in the control of adaptive learning, visual-motor coordination, and in the last twenty years there has been particular interest in the role of the cerebellum in cognitive functions.

Several studies have brought to the fore the essential contribution of the cerebellum to the regulation of neurocognitive functions, directed by specific brain regions with which the cerebellum is reciprocally linked, such as speech, cognitive processing and emotional regulation (Andreou et al., 2007; Basson & Wingate, 2013; Becker & Stoodley, 2013; Kasselimis et al., 2008; Sveljio et al., 2014; Vlachos et al., 2007). With its uniform cortical architecture, the cerebellum's connectional specificity allows it to modulate a wide array of behaviors (Vlachos et al., 2007).

Emerging evidence implicates cerebellar abnormalities and/or dysfunction in several developmental disorders, including Autism Spectrum Disorder (ASD) (Sydnor & Aldinger, 2022, Vlachos, 2018), This disorder is manifested in poor social interaction, atypical language use, and repetitive behaviors (Amaral et al., 2018; Bailey et al., 1996).

The first neuroanatomical differentiation observed in the brain of individuals with ASD was smaller cerebellar hemispheres and the hypoplasia of the cerebellar vermis in lobes VI and VII (Courschesne et al., 1988). Since then, many studies have found cerebellar abnormalities in the brains of individuals with ASD. For example, D'Mello et al. (2015) reported reduced gray matter in lobe VII in individuals with autism and showed a correlation between this component and the severity of a number of behavioral and cognitive deficits. These deficits included difficulty in social interaction, communication, and an increased number of stereotypical behaviours.

Subsequent studies across various disciplines have consistently implicated cerebellar circuits in ASD's social cognition and pathophysiology (Mosconi et al., 2015). Numerous studies have demonstrated overlapping features between cerebellar dysfunction and ASD symptoms, affecting language development, reading, working memory, executive function, and emotional behavior (Andreou et al., 2007; Bhat, 2021; Geschwind, 2009; Lord, 2020; Vlachos et al., 2007). Recent research by Couto-Ovejero et al. (2023) has highlighted the cerebellum's role in emotional regulation in autism, suggesting that deficits in internal model calibration may underlie emotional dysregulation.

Overall, cerebellar deficits have been associated with ASD for over three decades. According to Hampson and Blatt (2015), the cerebellum is - if not the only one - one of the main structures that exhibits non-standard morphology and functionality in individuals with ASD and is responsible for differential functioning across a wide range of behaviours, including communication skills, social interaction, stereotypic/repetitive behaviours, motor coordination and higher cognitive processes. This study aims to evaluate cerebellar function

in preschool children with ASD compared to age-matched typically developing children at a behavioral level.

Methods

Participants

A total of 40 children took part in this study. Twenty children, diagnosed with Autism Spectrum Disorder (ASD) according to the DSM-V criteria, with a mean age of 4.51 (SD = .06), were paired with 20 typically developing children (TD) matched for age and gender, with a mean age of 4.70 (SD = .08). All participants were enrolled in preschool education centers in North Greece at the time of data collection.

Materials & Procedure

All participants underwent assessment which consisted of seven clinical tests (Dow & Moruzzi, 1958) designed to evaluate three main areas of cerebellar function: a) maintenance of posture, b) hypotonia (reduced muscle tone), and c) complex movements (Fawcett et al., 1996). Specifically, these tests evaluated: 1) limb shake, 2) hand declination, 3) balance time, 4) postural stability, 5) weighting time, 6) past pointing, and 7) toe tapping. The abovementioned tests were administered at the children's schools by a trained researcher. Each child was assessed separately in a classroom setting, with each procedure lasting between 20 and 30 minutes, following the same test administration order.

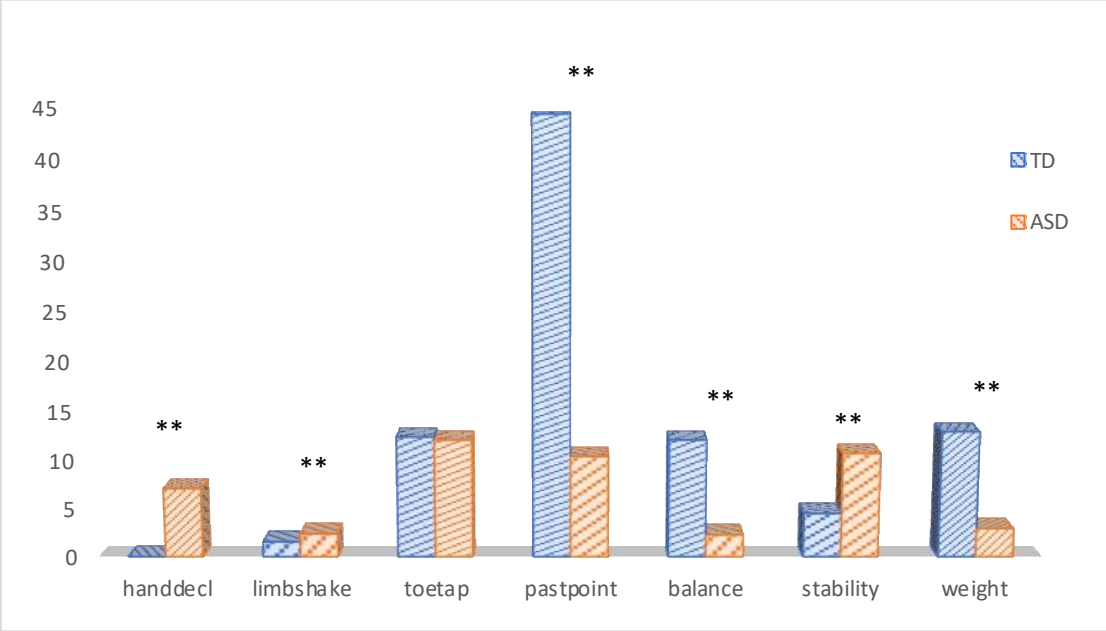
Data Analysis

Data analysis was conducted using SPSS for Windows 25.0. A series of one-way univariate analysis of variance (ANOVA) tests were performed to ascertain whether mean scores on the above-mentioned cerebellar tests differed significantly across the three groups. Sheffe's post–hoc tests were undertaken whenever significant group differences were detected.

Results

Group performance means and standard deviations on the seven cerebellar tests for the two groups of participants are presented graphically in Figure 1. Children with ASD performed significantly lower in 6 out of 7 cerebellar tests namely hand declination, limb shake, past pointing, balance time, postural stability and weighting time compared to children with TD (Figure 1).

More specifically, the group of children with ASD showed statistically significant lower scores than the TD children in six clinical tests: limb shake ($F_{2,57} = 23.34$; $p < 0.01$), hand declination ($F_{2,57} = 6.92$; $p < 0.01$), past pointing ($F_{2,57} = 183.23$; $p < 0.01$), balance time ($F_{2,57} = 895.55$; $p < 0.01$), postural stability ($F_{2,57} = 271.17$; $p < 0.01$) and weighting time ($F_{2,5\ 7} = 38.70$; $p < 0.01$). The toe topping test was the only test where statistically significant differences were not found between the two groups ($F_{2,57} = 1.68$; $p = 0.9$).



***p<0.01*

Figure 1: Performance of the TD and ASD children on the 7 cerebellar tests

Discussion & Conclusions

This study aimed to assess the cerebellar function of preschool children diagnosed with autism spectrum disorder (ASD) compared to typically developing children, focusing on behavioral aspects. Our findings indicate compromised cerebellar-dependent motor behaviors -specifically, maintenance of posture, hypotonia, and complex movements-in preschoolers with ASD. This aligns with previous research demonstrating deficits in tasks related to cerebellar function in individuals with ASD, suggesting a partial contribution of cerebellar dysfunction to ASD symptoms (Cundari et al., 2023).

Consistent with existing literature, our study supports the notion of general cerebellar dysfunction in children with ASD (Bhat, 2021; Craig et al., 2018). Our results are also in line with neuroanatomical studies which reported significantly larger total cerebellar and cerebellar white matter volumes in young children with ASD compared to typically developing controls, suggesting early alterations in cerebellar development (Sparks et al., 2002; Courchesne et al., 2001). Recent research extends these findings to younger ages, indicating that familial risk of ASD may impact cerebellar development as early as 4-6 months of age (Pote et al., 2019). Additionally, reduced total cerebellar white matter volume was also observed in preschool children with ASD (Lucibello et al., 2019). These findings suggest that early neuroanatomical alterations, dysfunction, or damage to the cerebellum may have lasting effects on movement, cognition, and emotional regulation.

While cerebellar dysfunction likely contributes to ASD symptoms, it is not necessarily the primary cause of ASD. Rather, the cerebellum likely plays an important role in the neural alterations associated with ASD. Further neuroimaging studies are needed to elucidate the cerebellum's role in both typical and atypical behavior and cognitive functioning.

Based on the evidence reported in the present study, we suggest including assessment of cerebellar function in ASD diagnosis protocols, with reported deficits considered as one of

the criteria for early ASD diagnosis. Early intervention targeting motor, cognitive, and social skills is crucial for promoting developmental milestones and reducing symptom severity in children with ASD (Geschwind et al., 2009; Hirata, 2014).

References

Amaral, D.G., Shumann, C.M., Nordahl, W.C. (2008). Neuroanatomy of autism. *Trends in Neuroscience, 31,* 137-145.

Andreou, G., Vlachos, F., & Haftouras, N. (2007). The cerebellum and language functions. *Psychology: The Journal of the Hellenic Psychological Society, 14*(2), 113-126.

Bailey, A., Philips, W., Rutter, M. (1996). Autism towards an integration of clinical, genetic, neuropsychological perspectives. *Journal of Child Psychology & Psychiatry, 37,* 89-126.

Basson, M.A, Wingate, R.J (2013). Congenital hypoplasia of the cerebellum: developmental causes and behavioral consequences. *Frontiers in Neuroanatomy, 7,* 29, doi:10.3389/fnana.2013.00029

Becker, E.B., Stoodley, C.J (2013). Autism spectrum disorder and the cerebellum. *International Review of Neurobiology,* 113, 1-34.

Bhat, N.A. (2021). Motor impairment increases in children with autism spectrum disorder as a function of social communication, cognitive and functional impairment, repetitive behavior severity and comorbid diagnoses: a SPARK study report. *Autism research, 14*(1), 202-219.

Courchesne, E., Karns, C. M., Davis, H. R., Ziccardi, R., Carper, R. A., Tigue, Z. D., … Courchesne, R. Y. (2001). Unusual brain growth patterns in early life in patients with autistic disorder: An MRI study. *Neurology, 57*, 245–254.

Courchesne, E, Yeung- Courchesne, R., Press, G.A., Hesselink, J.R., Jernigan, T.L (1988). Hypoplasia of the cerebellar lobules VI and VII in Autism. *The New England Journal of Medicine, 318,* 1349-1354.

Couto-Ovejero, S., Ye, J., Kind, P.C., Till, S.M.& Watson, T.C. (2023). Cerebellar contributions to fear-based emotional processing: relevance to understanding the neural circuits involved in autism. *Frontiers in System Neuroscience, 17,* 1229627. doi:10.3389/fnsys.2023.1229627

Craig, F., Lorenzo, A., Lucarelli, E., Russo, L., Fanizza, I., Tabacca, A. (2018). Motor competency and social communication skills in preschool children with autism spectrum disorder. *Autism Research, 11,* 893-902.

Cundari, M., Vestborg, S., Gustafsson, P., Gorcenco, S., & Rusmussen, A. (2023). Neurocognitive end cerebellar function in ADHD, autism and spinal cerebellar ataxia. *Frontiers in Systems Neuroscience, 17*:1168666. doi:10.3389/fnsys.2023.1168666

D¨Mello, A. M., Crocetti, D., Mostofsky, S.H., et al. (2015). Cerebellar grey matter and lobular volumes correlate with core autism symptoms. *Neuroimage Clinical, 7,* 631-639.

Dow, R., & Moruzzi, G. (1958). *The physiology and pathology of the cerebellum*. Minneapolis: University of Minnesota Press.

Fawcett, A. J., Nicolson, R. I., & Dean, P. (1996). Impaired performance of children with dyslexia on a range of cerebellar tasks. *Annals of Dyslexia, 46,* 259-283.

Geschwind, D.H. (2009). Advances in autism. *Annual Review of Medicine, 60,* 367-380.

Hampson, D. R., & Blatt, G. J. (2015). Autism spectrum disorders and neuropathology of the cerebellum. *Frontiers in neuroscience, 9,* 160226.

Hirata, S., Nakai, A., Okuzumi, H, Kitajma, Y., Hosobuchi, T., Kokobun, M. (2014). Relationship between motor skill and social impairment in children with autism spectrum disorders. *International Journal of Developmental Disorders, 60,* 251-256.

Kasselimis, D., Margarity, M., & Vlachos, F. (2008). Cerebellar function, dyslexia and articulation speed. *Child Neuropsychology, 14,* 303-313.

Lord, C., Brugha, T.S., Charman, T., Cusack, J. et al. (2020). Autism Spectrum Disorder. *Nature Reviews Disease Primers, 6*(1):5. doi:10.1038/s41572-019-0138-4

Lucibello, S., Verdolotti, T., Giordano, F.M., Lapenta, L., Infante, A., Piludu, F., et al. (2019). Brain morphometry of preschool age children affected by autism spectrum disorder: correlation with clinical findings. *Clinical Anatomy, 32,* 143–150.

Mosconi, W. M., Wang, Z., Schmitt, M. L., Tsai, P., Sweeney, J. A. (2015). The role of cerebellar circuitry alterations in the pathophysiology of autism spectrum disorders. *Frontiers in Neuroscience, 9*, 296. DOI:10.3389/fnins.2015.00296

Pote, I., Wang, S., Sethna, V., Blasi, A., Daly, E., Kuklisova-Murgasova, M., ... & BASIS Team. (2019). Familial risk of autism alters subcortical and cerebellar brain anatomy in infants and predicts the emergence of repetitive behaviors in early childhood. *Autism Research, 12*(4), 614-627.

Schmahmann, J. D. (2001). The cerebrocerebellar system: Anatomic substrates of the cerebellar contribution to cognition and emotion. *International Review of Psychiatry, 13,* 247–260.

Sparks, B. F., Friedman, S. D., Shaw, D. W., Aylward, E. H., Echelard, D., Artru, A. A., … Dager, S. R. (2002). Brain structural abnormalities in young children with autism spectrum disorder. *Neurology, 59,* 184–192.

Sveljo, O., Culić, M., Koprivšek, K., Lučić, M. (2014). The functional neuroimaging evidence of cerebellar involvement in the simple cognitive task. *Brain Imaging and Behavior, 8*, 480-486. doi:10.1007/s11682-014-9290-3

Sydnor, L.M. & Aldinger, K.A. (2022). Structure, function and genetics of the cerebellum in autism. *Journal of Psychiatry & Brain Science,7,* e220008, doi:10.20900/jpbs.20220008

Vlachos, F. (2018). *Brain learning and special education.* Athens: Gutenberg.

Vlachos, F., Papathanasiou, I., & Andreou, G. (2007). Cerebellum and reading *Folia Phoniatrica et Logopaedica, 59*, 177-183.

Vlachos, F., Tsiftzi, F., & Agapitou, P. (2007). Evidence of cerebellar dysfunction in low-functioning children with autism. *Cognition Brain Behavior, 11,* 507-517.

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