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Evaluation of Podalic Support and Monitoring of Balance Control in Children with and without Dyslexia: A Pilot Study

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Abstract: Background: The American Psychiatric Association has identified dyslexia as a neurobiological disorder. The aim of the study was to evaluate podalic support, balance control, and dyslexia's effects on interpersonal relationships. **Methods:** Fifty-seven subjects were enrolled for this study. The subjects were divided into two groups. The experimental group was composed of children with diagnosis of dyslexia. The control group was composed of healthy subjects. Each subject underwent baropodometry and posturographic analysis. In addition, the Multidimensional Self-esteem Assessment test by Bracken was used for a precise measurement of self-esteem in both groups (TMA). **Results:** The static baropodometry and posturographic results of the experimental group were significantly higher compared to the control group. The analysis showed significant differences: Surface left and right, Surface forefoot left, Surface forefoot right, Retro foot surface left, Retro foot surface right, and the Ellipse surface area. The test for multidimensional self-esteem assessment (TMA) analysis showed a significant difference. The Pearson correlation index showed a high correlation between the following parameters: Surface ellipse vs. TMA; Length of sway path vs. average speed of movement. **Conclusion:** The dyslexic children showed a flat-footed trend and an unstable balance compared with healthy subjects. Furthermore, the Multidimensional Self-Esteem test showed significantly lower self-assessments in the experimental group compared to control group.

Keywords: dyslexia; flat feet; static baropodometry; balance; posture; posturography

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1. Introduction

Developmental Dyslexia is a neurodevelopmental disorder generally characterized by an impaired ability to accurately decode single written words by using rules of correspondence between letters and sounds, as well as to read quickly and without errors. As defined in DSM-5 [1], diagnostic criteria include reading accuracy skills that are below those expected for chronological age and interfere with school achievement and everyday life (prevocational/vocational, leisure, and play activities). Symptoms should not be due to intellectual disability, linguistic, visual, auditory, neurological impairment, or adverse conditions (e.g., inadequate instruction, low socio-economic background), and they persist despite the provision of extra help or targeted instruction. Epidemiological studies reveal rates of developmental dyslexia in school-age children and adolescents ranging between 2.5% and 3.5%. As early as 1993, Galaburda et al. described that, during early brain development, the dyslexic brain showed anomalous migration patterns such as cortical ectopias and misplaced magnocells in the thalamus [2]. Consequently, dyslexia can be considered a neurobiological syndrome that incidentally only affects reading. However, while reading disability is the primary diagnostic criterion, dyslexic individuals often experience a variety of other problems [3]. There is an increasing emphasis on the analysis of motor skills. Motor deficits in children with developmental dyslexia have been described in many studies and discussed long since [4]. However, the prevalence rate of these deficits is not clear. The literature showed that one important cause of dyslexic reading problems is probably auditory and visual sequencing [5,6]; sequencing depends on accurate timing of auditory and visual sensory inputs. This is often known as temporal processing [7]. In 2019, John Stein explained that the neurons responsible for sequencing, magnocellular-type neurons, are required by all central nervous system networks, not just in the visual and auditory systems, but also in the somatosensory, proprioceptive, and motor systems [7]. In 1999, Nicolson et al. showed motor impairment in about 80% of their cases; almost all dyslexic children they studied reported balance, muscle tone, or co-ordination deficits [8]. In 2006, Yves Chaix et al. showed motor deficits in a population of children with dyslexia. The authors showed a significant relationship between attention deficit and motor involvement in dyslexia. These results suggest that different pathophysiological mechanisms come into play for reading deficits and motor deficits that may concern different regions of the central nervous system [8]. One study showed abnormalities in structural signals in cerebellar regions in adult dyslexics compared to healthy subjects [9]. The relationship between the dyslexia and the cerebellum deficit [10] confirmed the connectivity that existed between the cerebellum and the frontal cortex [11,12]; and strongly supports the role of the cerebellum in language-related tasks [13] and learning complex cognitive–motor skills, such as tool use [14]. According to the literature, postural control is influenced by dyslexia. With continuous updating, the postural control system is regulated by multisensory feedback [15]. In this context, the literature suggests that dyslexic children could have abnormal cerebellar functions, such as for skill automatization, time estimation, balance, and other cerebellar signs of dystonia [16]. Many studies demonstrated that dyslexic children have low postural control compared to non-dyslexic children [17–19]. In 2013, Viana et al. indicated that dyslexic children were more unstable than healthy children. The literature confirmed that the dyslexic subjects have significant differences in brain activation compared to control subjects [20]. In the cerebellum, bilateral regions are active during word reading [21]. In 2003, Vicari et al. showed that the motor learning could be deficient in children with dyslexia, and that this can be caused by cerebellar function [22]. Stoodley et al. demonstrated that dyslexic children have precarious balance compared to healthy peers. It should be pointed out that dyslexic children were worse on eyes-open balancing [23]. The authors have hypothesized that poor balancing is a symptom of a delayed or abnormally developing nervous system, which is further reflected in literacy difficulties [23]. The foot is a great access point for postural information. Another interesting aspect, but not studied in depth in the literature, is the effect that dyslexia can create on self-esteem, even indirectly. There is a relation between a gross motor incoordination upon and the self-esteem in children with school age. The postural deficits cause a certain amount of clumsiness in physical movements. Shaw et al. showed that there is significantly lower self-esteem in the gross motor-delayed children. In addition, the subjects with poor coordination rated themselves lower in social relationships. Finally, youngsters with gross motor delays were found to be significantly less happy [24].

Hypothesis Section

The aim of this pilot study was to evaluate the foot adaptations and the podalic surface, and to confirm the results reported in the literature on balance control deficits in children with diagnosis of dyslexia. In addition, we analyzed whether dyslexia has effects on interpersonal relationships.

2. Material and Methods

The study design was accepted by the Departmental Research Committee, and the subjects were selected according to the criteria approved by the Ethics Committee of the University of Palermo.

Fifty-seven subjects were enrolled in this study. Children were separated into two groups: Experimental group (EG) and control group (CG). The EG was composed of 22 children (Age: 11.91 ± 1.57 years; height: 148.2 ± 11.62 cm; weight: 47.32 ± 11.03 kg) with diagnosed dyslexia. This diagnosis had been certified by the Italian public health system. The CG was composed of 35 children with normal reading abilities (Age: 12.66 ± 0.63 years; height: 150.8 ± 9.13 cm; weight: 45.6 ± 11.26 kg). All measurements were performed twice, and the arithmetic mean was recorded for evaluation. Weight was measured with approximation to 100 g (Wunder 960 classic). Height was measured with a portable Seca stadiometer, sensitive to changes up to 1 cm (Seca 220, Hamburg, Germany). Measurements were done with children barefoot touching the stadiometer and the head in neutral position. The EG and CG children were recruited in schools of Palermo, Italy. In this study, we make use of some inclusion criteria to enroll the groups components: (1) Comparable age; (2) same geographical origin; and (3) not having took part in a structured motor activity program for at least a year. The subjects were enrolled according to the criteria endorsed by the ethics committee of the University of Palermo. The study was conducted in accordance with the Declaration of Helsinki, and the principles of the Italian data protection act (196/2003) were observed. Prior the start of the study, all parents provided informed consent. Following Houghton, K.M et al., we make use of some exclusion criteria: (1) Auditory or visual deficit (allowable if corrected with lens/glasses); (2) motor deficit involving the lower limbs; (3) having a positive diagnosis for any disease which influences the balance (benign paroxysmal positional vertigo [BPPV], labyrinthitis, Ménière disease, tinnitus, vestibular neuronitis, etc.) [25]. The analysis of the sample were collected from the research unit during the period between January 2017 and July 2017 at Department of Psychology and Educational Science, University of Palermo, and in a suitable school environment. The analysis of CG were collected in the same period and by the same research unit at the sports science center, University of Palermo.

2.1. *Method of Testing*

Procedure

The static baropodometry analyses was managed with the FreeMed software (the FreeStep v.1.0.3 software, produced by Sensor Medica, Guidonia Montecelio, Roma, Italy). The platform's sensors are 24K gold; this allows high repeatability and reliability [26]. Using the Romberg test position, all subjects were administered podalic analysis on the baropodometric platform. The settings of the platform were adjusted before making the first measurement and were retained for all measurements. Two tests were performed on each sample; the best performance was used for the analysis. The parameters used for balance investigation were: Surface left (SX), Surface right (DX), Surface forefoot left (SX), Surface forefoot right (DX), Retro foot surface left (SX), and Retro foot surface right (DX) [27–29]. In addition, the posturography analysis was used to evaluate the balance control. The analysis was performed twice, and the scores obtained the second time were used for data analysis [30]. For the posturography assessment, each subjects performed the Romberg test with standardized positioning. Posturography values were measured using the FreeMed posturography system, including the FreeMed baropodometric platform and FreeStep v.1.0.3 software. The system had been calibrated to sample postural sway at 25 Hz, in real time. The parameters of postural analysis: CoP = Center of pressure (COP) is the point of location of the vertical ground reaction force vector; length of sway path (mm)= the total distance covered by CoP in a precise time; ellipse surface area (mm^2) = the dispersion of the oscillations, which contains 95% of the sampled positions of the CoP; x-mean (mm) = midpoint of the oscillations coordinates of the CoP along the frontal planes (X; right-left); y-mean (mm) = midpoint of the oscillations coordinates of the CoP along the sagittal planes (Y; forward-backward); Average speed of movement = mean velocity of the COP. The following parameters of the statokinesigram were considered in open eye conditions: Length of sway path of the CoP; ellipse surface area; average speed of movement; coordinates of the CoP along the frontal (x-mean) and sagittal (y-mean) planes [28].

The ellipse surface area and the coordinates along the frontal and sagittal parameters were used and cannot be modified significantly by the sampling rate, according to the 1981 Kyoto conventions [27,31].

TMA: Test for multidimensional self-esteem assessment.

Self-esteem is a form of self-evaluation conducted by the individual based on his or her past experiences, which allows him or her to predict future behavior. Self-esteem is assessed by asking the subjects how much they are in agreement with a series of assertions, following the theory that these evaluations are in relation to the self-perception of one's own experience and of the ways with which the subjects interacted with others. The TMA test by Bracken (Multidimensional Self-Esteem Test) allows a precise measurement of self-esteem in developmental age [32].

The TMA consists of 6 sub-tests:

(1) Interpersonal relationships
(2) Competence in environmental control
(3) Emotionality
(4) Scholastic success
(5) Family life
(6) Body experience

In this study, we administered to the sample only the first area items (25 items; interpersonal relationships) as they comply with the objective of the study.

2.2. Administration and Scoring

There are no time limits; each question includes 4 probable alternative answers:

(1) Absolutely true
(2) True
(3) Not true
(4) Absolutely not true

The researcher will assign a score ranging from 4 to 1 [32]. The total score was not used to make a self-assessment of the subjects (then using the TMA manual to interpret the data), but the raw data were exclusively compared with the control group and correlated with the posturography parameters to investigate the differences in the EG group compared to the healthy group.

2.3. Statistical Analysis

All numerical data were entered on an Excel sheet before being analyzed. Shapiro–Wilk's normality test was used to analyze data distribution. To evaluate the statistical differences between measurements, the unpaired t-test or Mann Whitney test independent variables were used, when appropriate. A *p* value lower than 0.05 was considered useful. The Pearson correlation index was used to analyze the correlations between the variables. To perform the analysis, StatSoft's STATISTICA software (Windows, Vers. 8.0; Tulsa, OK, USA) was used.

3. Results

As previously mentioned, fifty-seven subjects were recruited for the study (EG: 22; CG: 35). The anthropometric data of the two groups are shown in Table 1.

Table 1. Description of the anthropometric analysis between groups.

	EG (22)	CG (35)	*p*<
Age, y	11.91 ± 1.57	12.66 ± 0.63	ns
Height, cm	148.2 ± 11.62	150.8 ± 9.13	ns
Weight, Kg	47.32 ± 11.03	45.66 ± 11.26	ns
Shoe number	38.39 ± 2.66	38.69 ± 2.12	ns

The analysis of anthropometric differences showed no statistically significant differences. Excluding TMA and mean Y, the Shapiro–Wilk normality test showed that all variables had a non-Gaussian distribution. Consequently, the Student's or Mann Whitney's test was used. The results are described in Table 2 and Figures 1 and 2.

Table 2. Description of the analysis between groups.

	EG (22)	CG (35)	*p*<
*** TMA**	69 ± 15.30	77.17 ± 12.73	$p < 0.05$
† Surface SX, cm^2	96.68 ± 16.51	55.66 ± 18.78	$p < 0.001$
† Surface DX, cm^2	95.27 ± 16.25	55.51 ± 17.42	$p < 0.001$
† Surface forefoot SX, cm^2	50.77 ± 10.50	27.77 ± 10.50	$p < 0.001$
† Surface forefoot DX, cm^2	50.05 ± 9.92	27.74 ± 12.43	$p < 0.001$
† Retro foot surface SX, cm^2	45.95 ± 8.27	27.86 ± 7.28	$p < 0.001$
† Retro foot surface DX, cm^2	45.27 ± 7.73	27.80 ± 7.112	$p < 0.001$
† Ellipse, mm^2	553.6 ± 271.4	318.6 ± 270.6	$p < 0.001$
† Length of sway path, mm	771.3 ± 244.9	836.9 ± 231.2	ns
† Average speed of movement, mm/s	15.98 ± 5.01	16.36 ± 4.52	ns
† X mean, mm	3.563 ± 14.05	–7.160 ± 10.03	$p < 0.001$
*** Y mean, mm**	–22.72 ± 9.58	–29.89 ± 14.20	$p < 0.05$

* the unpaired t-test; † Mann Whitney test; DX: Right; SX: Left.

Moreover, the Pearson correlation index showed a high correlation between the following parameters: Surface ellipse vs. TMA (r = –0.74); Length of sway path vs. average speed of movement (r = 0.95). The graphic representation is described in Figures 3 and 4. The correlations are significant at $p < 0.05$.

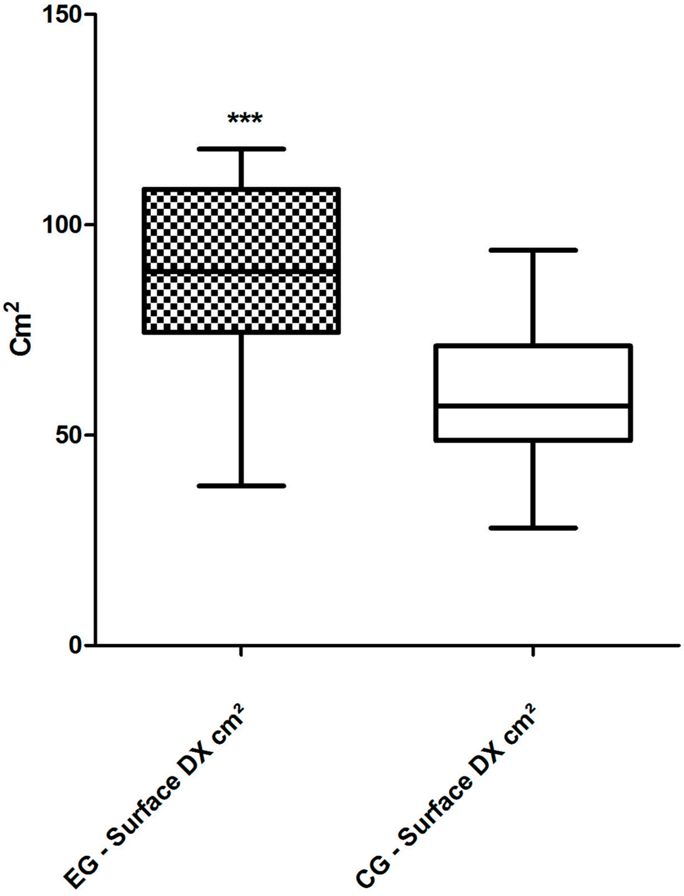

Figure 1. The analysis of foot surface right (DX). (***: $p < 0.001$).

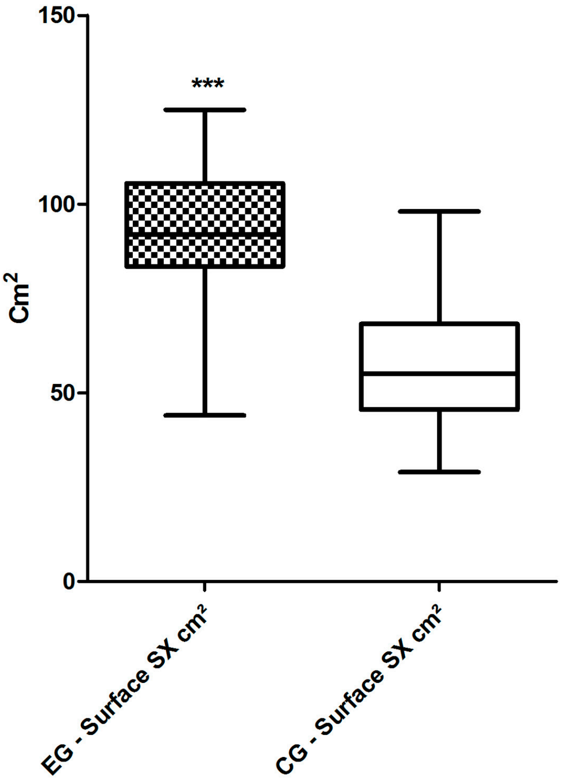

Figure 2. The analysis of foot surface left (SX). (***: $p < 0.001$).

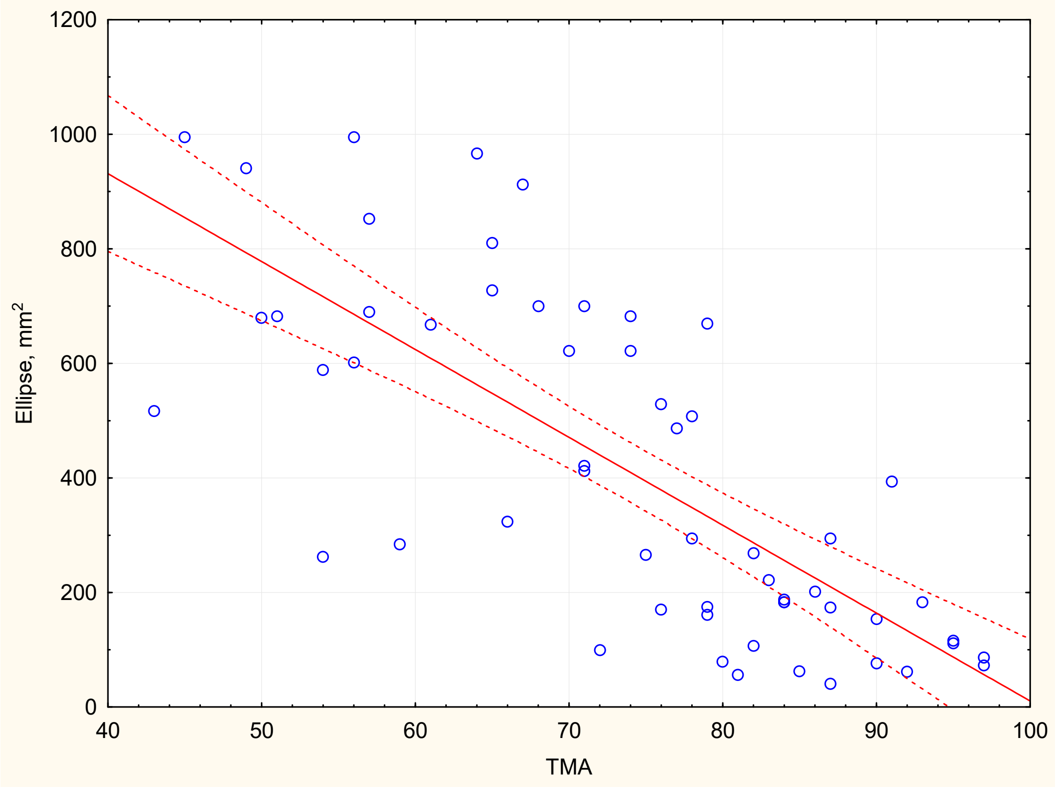

Figure 3. The Pearson correlation index between surface ellipse and test for multidimensional self-esteem assessment (TMA).

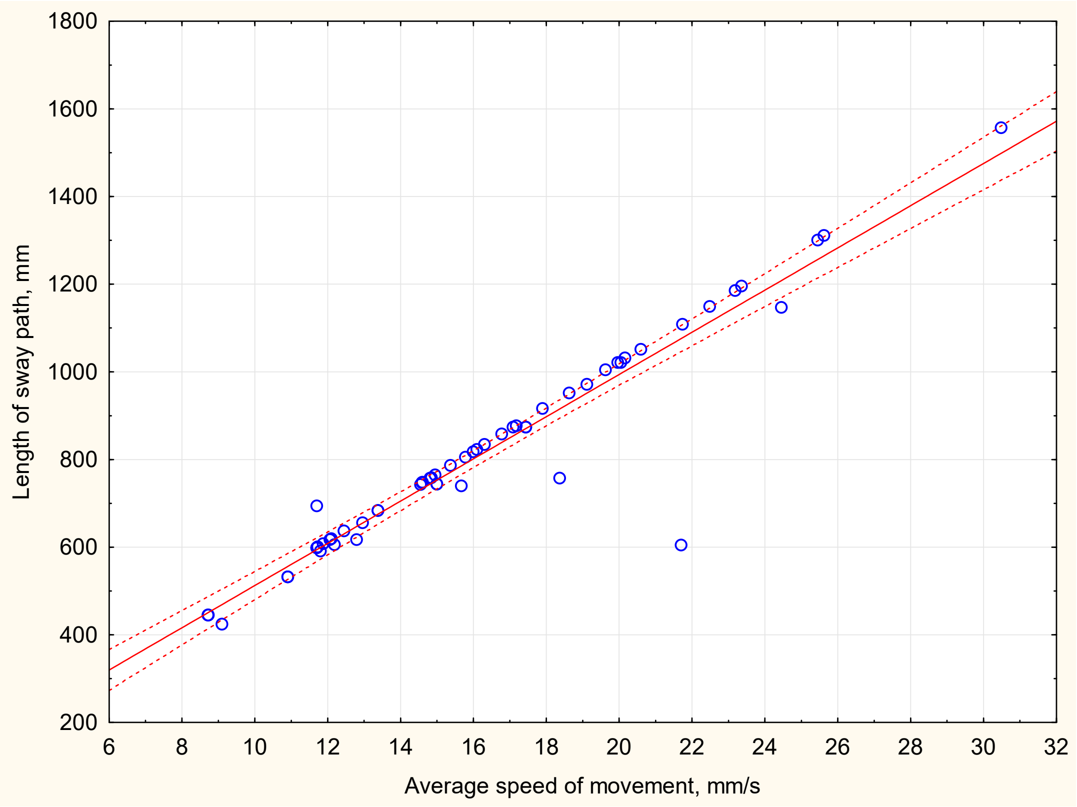

Figure 4. The Pearson correlation index between length of sway path and average speed of movement.

4. Discussion

Dyslexic children showed a flat-footed trend (surface DX and SX parameters, Figures 3 and 4). To our knowledge, this is the first study that evaluated the effect of dyslexia on the surface of feet. Flat feet are a postural deficit in which the curves of the foot are decreased. As a consequence, the sole of the foot comes into contact completely or near-completely with the ground. In 2005, Stoodley et al. showed an impaired balancing ability in dyslexic children. The flat foot can affect gait biomechanics and risk of lower extremity injury [33]. In children, the most common form of flat foot is "the infantile loose foot", caused by various deficits: Insufficient muscle development of the foot, ligamentous laxity, increased adipose tissue, and immature neuromuscular control [34,35]. The foot often plays an important role in physical activity, and is advantageous for a healthy lifestyle. Foot problems can reduce a routine physical activity and perpetuate the obesity cycle, and impoverish motor patterns and motor skill. Furthermore, when activity is reduced, this leads to abnormalities in myosin composition in the muscles and a delayed regression of polyneural innervations [36]. Some studies suggest that the deficits of dyslexia extend well beyond the phonological domain [37]; one of these areas is in motor control [18]. Nicolson, Fawcett, and Dean suggest that cerebellar dysfunction in dyslexia not only limits the extent of cognitive skills such as reading, but also motor control and coordination [38]. In 2018, Helen A. Banwell et al. showed the various causes of flat feet; the deficit of neuromuscular control was significant in this study. Fawcett et al. showed that over 95% of dyslexic children had clear evidence of impaired muscle tone and stability [39]. Furthermore, the mechanoreceptor sensitivity of the foot sole has been shown to be directly related to balance control [40]. The mechanoreceptor of the foot using many types of perception tasks, however, may be influenced by the attention of the subjects [41]. In this line of thought, Wimmer et al. [42] and Raberger and Wimmer [43] hypothesized that balance deficits in dyslexic children could be due to the frequent co-morbidity among dyslexia and ADHD. In addition, Jarl Flensmark showed that the plantar surface and the Golgi tendon organs are connected with the function of the cerebellar system [44]. The lack of an explanation for a direct link between motors deficits dyslexia and the flat-foot is the limitation of this study, and will be the subject of future studies. The balance analysis showed an instability control in Dyslexic children. Posturography measures the oscillations the body of subjects in a standing position. The ellipse surface area quantifies the surface in mm^2, which includes the variations of the oscillations of body. In our sample, the EG group was significantly more unstable than the CG group (Table 2; $p < 0.001$). Furthermore, it is interesting to note that dyslexic children have a more anteriorized center of balance and tend to have average oscillations on the right of the transversal axis compared to healthy children, who tend instead to oscillate towards the left; the differences were always significant, as shown in Table 2. In addition to this, a part of the Multidimensional Self-Esteem Test (TMA) was administered to the sample. The analysis of the data (Table 2) shows that the self-evaluations of the EG group are significantly lower compared to the evaluations of the CG group ($p < 0.05$); furthermore, the Pearson index analysis showed an inverse correlation with the ellipse parameter ($r = -0.74$; Figure 1). This would seem to indicate that the more negative the postural stability (wide ellipse), the more negatively it affects interpersonal relationships (low scores on the first 25 TMA Items). In 2012, Nelson et al. showed a relationship between dyslexia and depression. The subjects with dyslexia were significantly associated with depressive and anxiety related symptoms [45]. In 2018, Nelson himself showed depressive symptoms and anxiety-related symptoms with poor reading-related skills [46]. In addition, the Pearson index indicates that, with postural instability, the speed of the foot support to second ratio increases ($r = 0.95$; Figure 2). This result was not particularly surprising; the postural system, unable to find a stable support, continuously corrects, and therefore the speed of support tends to increase in unstable subjects. Our data did not confirm the results showed, in 2017, by Gouleme et al. [47]; the authors described how mean velocity of the CoP were significantly greater in the dyslexic children compared to the non-dyslexic children. On the contrary, our results showed no significant difference. In conclusion, the literature confirmed that the phenotype of dyslexia often encompasses many information processing deficits that extend well-beyond the phonological domain [37,48]. Previous studies have reported balance and postural deficits that are associated with dyslexia [18,23,49]. However, in the literature, there is a small number of studies that have analyzed the postural tonic system in dyslexic subjects, especially in children. The results of Gouleme et al. are in line with our data [50]. The authors showed that poor postural control in dyslexic children was associated with a deficit in using sensory information caused by impairment in cerebellar activity [50]. Furthermore, the TMA results showed that children with undiagnosed dyslexia can have years of frustration, suffering, marginalization, loss of self-esteem, and loss of opportunities. Dyslexics can suffer from clumsiness and delayed motor milestones, temporal sequencing problems (telling time, remembering the months of the year), and poor spatial sequencing [23]. On the contrary, if dyslexia is diagnosed early, these children can take advantage of compensatory tools that can help them. Particularly interesting is the tendency of these subjects to be flat-footed, which not only supports the cerebellar theory and the muscle tone deficit reported in the literature, but, if confirmed by further studies, could be inserted in a series of anamnestic data to identify the subjects at risk of dyslexia. However, there are two main the limitations of this study: The analyzed sample is reduced to define certain conclusions and, moreover, it has not been possible to clearly explain the neurophysiological pattern of the breech hypotonic of dyslexic children. The cerebellum could affect the deficits of dyslexia in a variety of ways. In its role as an important timing structure linking the sensory and motor regions of the brain, the cerebellum may therefore contribute to the many problems found in dyslexia. The literature showed that the subjects with dyslexia had motor ability restricts. Stoodley et al. showed that there are differences regarding the relationship between motor and literacy skills between dyslexic and healthy children. Whether or not motor ability restricts or affects the acquisition of literacy skills remains to be seen. It is possible that poor balancing is a symptom of a delayed or abnormally developing nervous system, which is further reflected in literacy difficulties [23]. Our results suggest that different pathophysiological mechanisms come into play, which may affect different regions of the central nervous system, thus confirming the conclusions of Nicolson et al. [8]. However, the postural system is a cybernetic system, and therefore very complicated to identify a precise cause. Finally, further studies are needed to confirm these data, but if our conclusions are correct, it would be right to insert a training protocol to improve the balance deficit and the quality of life in children with dyslexia.

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References

1. American Psychiatric Association; DSM-5 Task Force. *Diagnostic and Statistical Manual of Mental Disorders: Dsm-5*, 5th ed.; American Psychiatric Association: Washington, DC, USA, 2013; p. xliv. 947p.
2. Galaburda, A.; Livingstone, M. Evidence for a magnocellular defect in developmental dyslexia. *Ann. N. Y. Acad. Sci.* **1993**, *682*, 70–82. [CrossRef] [PubMed]
3. Stein, J. The magnocellular theory of developmental dyslexia. *Dyslexia* **2001**, *7*, 12–36. [CrossRef] [PubMed]
4. Denckla, M.B.; Rudel, R.G.; Chapman, C.; Krieger, J. Motor proficiency in dyslexic-children with and without attentional disorders. *Arch. Neurol.* **1985**, *42*, 228–231. [CrossRef] [PubMed]
5. Stein, J.; Walsh, V. To see but not to read; the magnocellular theory of dyslexia. *Trends Neurosci.* **1997**, *20*, 147–152. [CrossRef]
6. Vidyasagar, T.R.; Pammer, K. Dyslexia: A deficit in visuo-spatial attention, not in phonological processing. *Trends Cogn. Sci.* **2010**, *14*, 57–63. [CrossRef]
7. Stein, J. The current status of the magnocellular theory of developmental dyslexia. *Neuropsychologia* **2019**, *130*, 66–77. [CrossRef]
8. Nicolson, R.I.; Fawcett, A.J.; Berry, E.L.; Jenkins, I.H.; Dean, P.; Brooks, D.J. Association of abnormal cerebellar activation with motor learning difficulties in dyslexic adults. *Lancet* **1999**, *353*, 1662–1667. [CrossRef]
9. Eckert, M.A.; Leonard, C.M.; Richards, T.L.; Aylward, E.H.; Thomson, J.; Berninger, V.W. Anatomical correlates of dyslexia: Frontal and cerebellar findings. *Brain* **2003**, *126*, 482–494. [CrossRef]
10. Nicolson, R.I.; Fawcett, A.J. Procedural learning difficulties: Reuniting the developmental disorders? *Trends Neurosci.* **2007**, *30*, 135–141. [CrossRef]
11. Kelly, R.M.; Strick, P.L. Cerebellar loops with motor cortex and prefrontal cortex of a nonhuman primate. *J. Neurosci. Off. J. Soc. Neurosci.* **2003**, *23*, 8432–8444. [CrossRef]
12. Middleton, F.A.; Strick, P.L. Cerebellar projections to the prefrontal cortex of the primate. *J. Neurosci. Off. J. Soc. Neurosci.* **2001**, *21*, 700–712. [CrossRef]
13. Marien, P.; Engelborghs, S.; Fabbro, F.; De Deyn, P.P. The lateralized linguistic cerebellum: A review and a new hypothesis. *Brain Lang.* **2001**, *79*, 580–600. [CrossRef] [PubMed]
14. Imamizu, H.; Kuroda, T.; Miyauchi, S.; Yoshioka, T.; Kawato, M. Modular organization of internal models of tools in the human cerebellum. *Proc. Natl. Acad. Sci. USA* **2003**, *100*, 5461–5466. [CrossRef] [PubMed]
15. Mergner, T.; Rosemeier, T. Interaction of vestibular, somatosensory and visual signals for postural control and motion perception under terrestrial and microgravity conditions—A conceptual model. *Brain Res. Brain Res. Rev.* **1998**, *28*, 118–135. [CrossRef]
16. Fawcett, A.J.; Nicolson, R.I.; Dean, P. Impaired performance of children with dyslexia on a range of cerebellar tasks. *Ann. Dyslexia* **1996**, *46*, 259–283. [CrossRef]

17. Vieira, S.; Quercia, P.; Michel, C.; Pozzo, T.; Bonnetblanc, F. Cognitive demands impair postural control in developmental dyslexia: A negative effect that can be compensated. *Neurosci. Lett.* **2009**, *462*, 125–129. [CrossRef]
18. Barela, J.A.; Dias, J.L.; Godoi, D.; Viana, A.R.; de Freitas, P.B. Postural control and automaticity in dyslexic children: The relationship between visual information and body sway. *Res. Dev. Disabil.* **2011**, *32*, 1814–1821. [CrossRef]
19. Legrand, A.; Bui-Quoc, E.; Dore-Mazars, K.; Lemoine, C.; Gerard, C.L.; Bucci, M.P. Effect of a dual task on postural control in dyslexic children. *PLoS ONE* **2012**, *7*, e35301. [CrossRef]
20. Nicolson, R.I.; Fawcett, A.J. Automaticity: A new framework for dyslexia research? *Cognition* **1990**, *35*, 159–182. [CrossRef]
21. Fiez, J.A.; Petersen, S.E. Neuroimaging studies of word reading. *Proc. Natl. Acad. Sci. USA* **1998**, *95*, 914–921. [CrossRef]
22. Vicari, S.; Marotta, L.; Menghini, D.; Molinari, M.; Petrosini, L. Implicit learning deficit in children with developmental dyslexia. *Neuropsychologia* **2003**, *41*, 108–114. [CrossRef]
23. Stoodley, C.J.; Fawcett, A.J.; Nicolson, R.I.; Stein, J.F. Impaired balancing ability in dyslexic children. *Exp. Brain Res. Exp. Hirnforsch. Exp. Cereb.* **2005**, *167*, 370–380. [CrossRef] [PubMed]
24. Shaw, L.; Levine, M.D.; Belfer, M. Developmental double jeopardy: A study of clumsiness and self esteem in children with learning problems. *J. Dev. Behav. Pediatric JDBP* **1982**, *3*, 191–196. [CrossRef]
25. Houghton, K.M.; Guzman, J. Evaluation of static and dynamic postural balance in children with juvenile idiopathic arthritis. *Pediatric Phys. Ther.* **2013**, *25*, 150–157. [CrossRef]
26. Patti, A.; Bianco, A.; Messina, G.; Paoli, A.; Bellafiore, M.; Battaglia, G.; Iovane, A.; Traina, M.; Palma, A. The influence of the stomatognathic system on explosive strength: A pilot study. *J. Physi. Therapy Sci.* **2016**, *28*, 72–75. [CrossRef]
27. Gagey, P.M.; Weber, B. Study of intra-subject random variations of stabilometric parameters. *Med. Biol. Eng. Comput.* **2010**, *48*, 833–835. [CrossRef]
28. Patti, A.; Maggio, M.C.; Corsello, G.; Messina, G.; Iovane, A.; Palma, A. Evaluation of fitness and the balance levels of children with a diagnosis of juvenile idiopathic arthritis: A pilot study. *Int. J. Environ. Res. Public Health* **2017**, *14*, 806. [CrossRef]
29. Patti, A.; Bianco, A.; Paoli, A.; Messina, G.; Montalto, M.A.; Bellafiore, M.; Battaglia, G.; Iovane, A.; Palma, A. Pain perception and stabilometric parameters in people with chronic low back pain after a pilates exercise program: A randomized controlled trial. *Medicine* **2016**, *95*, e2414. [CrossRef]
30. Patti, A.; Bianco, A.; Sahin, N.; Sekulic, D.; Paoli, A.; Iovane, A.; Messina, G.; Gagey, P.M.; Palma, A. Postural control and balance in a cohort of healthy people living in europe: An observational study. *Medicine* **2018**, *97*, e13835. [CrossRef]
31. Kapteyn, T.S.; Bles, W.; Njiokiktjien, C.J.; Kodde, L.; Massen, C.H.; Mol, J.M. Standardization in platform stabilometry being a part of posturography. *Agressologie: revue internationale de physio-biologie et de pharmacologie appliquees aux effets de l'agression* **1983**, *24*, 321–326.
32. Bracken, B.A. *Test TMA—Valutazione Multidimensionale Dell'autostima*; Erickson: Trento, Italy, 2003.
33. Williams, D.S., III; McClay, I.S.; Hamill, J. Arch structure and injury patterns in runners. *Clin. Biomech.* **2001**, *16*, 341–347. [CrossRef]
34. Nemeth, B. The diagnosis and management of common childhood orthopedic disorders. *Curr. Probl. Pediatric Adolesc. Health Care* **2011**, *41*, 2–28. [CrossRef] [PubMed]
35. Sadeghi-Demneh, E.; Azadinia, F.; Jafarian, F.; Shamsi, F.; Melvin, J.M.; Jafarpishe, M.; Rezaeian, Z. Flatfoot and obesity in school-age children: A cross-sectional study. *Clin. Obes.* **2016**, *6*, 42–50. [CrossRef] [PubMed]
36. Ijkema-Paassen, J.; Gramsbergen, A. Development of postural muscles and their innervation. *Neural Plast.* **2005**, *12*, 141–151. [CrossRef]
37. Menghini, D.; Finzi, A.; Benassi, M.; Bolzani, R.; Facoetti, A.; Giovagnoli, S.; Ruffino, M.; Vicari, S. Different underlying neurocognitive deficits in developmental dyslexia: A comparative study. *Neuropsychologia* **2010**, *48*, 863–872. [CrossRef]
38. Nicolson, R.I.; Fawcett, A.J.; Dean, P. Developmental dyslexia: The cerebellar deficit hypothesis. *Trends Neurosci.* **2001**, *24*, 508–511. [CrossRef]
39. Fawcett, A.J.; Nicolson, R.I. Performance of dyslexic children on cerebellar and cognitive tests. *J. Mot. Behav.* **1999**, *31*, 68–78. [CrossRef]

40. Perry, S.D.; McIlroy, W.E.; Maki, B.E. The role of plantar cutaneous mechanoreceptors in the control of compensatory stepping reactions evoked by unpredictable, multi-directional perturbation. *Brain Res.* **2000**, *877*, 401–406. [CrossRef]
41. Schlee, G.; Neubert, T.; Worenz, A.; Milani, T.L. Children with adhd show no deficits in plantar foot sensitivity and static balance compared to healthy controls. *Res. Dev. Disabil.* **2012**, *33*, 1957–1963. [CrossRef]
42. Wimmer, H.; Mayringer, H.; Raberger, T. Reading and dual-task balancing: Evidence against the automatization deficit explanation of developmental dyslexia. *J. Learn. Disabil.* **1999**, *32*, 473–478. [CrossRef]
43. Raberger, T.; Wimmer, H. On the automaticity/cerebellar deficit hypothesis of dyslexia: Balancing and continuous rapid naming in dyslexic and adhd children. *Neuropsychologia* **2003**, *41*, 1493–1497. [CrossRef]
44. Flensmark, J. Physical activity, eccentric contractions of plantar flexors, and neurogenesis: Therapeutic potential of flat shoes in psychiatric and neurological disorders. *Med. Hypotheses* **2009**, *73*, 130–132. [CrossRef] [PubMed]
45. Nelson, J.M.; Gregg, N. Depression and anxiety among transitioning adolescents and college students with adhd, dyslexia, or comorbid adhd/dyslexia. *J. Atten. Disord.* **2012**, *16*, 244–254. [CrossRef] [PubMed]
46. Nelson, J.M.; Liebel, S.W. Socially desirable responding and college students with dyslexia: Implications for the assessment of anxiety and depression. *Dyslexia* **2018**, *24*, 44–58. [CrossRef]
47. Gouleme, N.; Villeneuve, P.; Gerard, C.L.; Bucci, M.P. Influence of both cutaneous input from the foot soles and visual information on the control of postural stability in dyslexic children. *Gait Posture* **2017**, *56*, 141–146. [CrossRef] [PubMed]
48. Loras, H.; Sigmundsson, H.; Stensdotter, A.K.; Talcott, J.B. Postural control is not systematically related to reading skills: Implications for the assessment of balance as a risk factor for developmental dyslexia. *PLoS ONE* **2014**, *9*, e98224. [CrossRef] [PubMed]
49. Bucci, M.P.; Gerard, C.L.; Bui-Quoc, E. The effect of a cognitive task on the postural control of dyslexic children. *Res. Dev. Disabil.* **2013**, *34*, 3727–3735. [CrossRef] [PubMed]
50. Gouleme, N.; Gerard, C.L.; Bui-Quoc, E.; Bucci, M.P. Spatial and temporal analysis of postural control in dyslexic children. *Clin. Neurophysiol.* **2015**, *126*, 1370–1377. [CrossRef] [PubMed]