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Sensory-based motor processing in children with specific learning disabilities

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Abstract

Introduction. Children with learning disabilities not only experience difficulties in academic performance but also exhibit neurological risks of motor and sensory processing. Evaluation of such a group might help identify their deficits even before early adolescence. The study aimed to assess sensory and motor problems in children with different types of specific learning disabilities.
Methods. A cross-sectional study was performed in students of 4th, 5th, and 6th grades in governmental schools, Cairo, Egypt. Overall, 200 children with poor scholastic achievement were screened with an intelligence quotient test (Raven's Progressive Matrices). The learning disabilities were evaluated with the Fathi al-Zayyat battery. Then, the Quick Neurological Screening Test was used to indicate motor and sensory problems.
Results. A total of 50 out of 772 screened children were confirmed to have learning disabilities (dyscalculia: 29, dyslexia: 11, mixed: 10), which represented 6.47% of the sample. Neurological signs were positive in all children with specific learning disabilities, while 82% of them were below average.
Conclusions. The study revealed that 82% of children with specific learning disabilities at 4th, 5th, and 6th grades were below age with a moderate discrepancy in the development of sensory and motor processes. The finger-to-nose test, double simultaneous stimulation of hand and cheek test, stand-on-leg test, and tandem walk test are associated with the type of specific learning disabilities (dyscalculia, dyslexia, or mixed).
Key words: specific learning disability, sensory processing, neurological soft signs, schoolchildren

Introduction

Specific learning disability (SLD) is a neurological condition in which the ability of the brain to carry out one or more academic tasks is impaired; examples of such tasks include reading (dyslexia), writing (dysgraphia), and mathematical reasoning (dyscalculia) during formal years of schooling [1, 2]. The biological causes of SLDs are innate predispositions; evidence implies that reading and mathematical reasoning disorders have a common genetic aetiology [3, 4]. Intellectual, emotional, visual, hearing, motor, or socioeconomic disturbances are not causes of SLD [5]. It is yet difficult to identify the children who are at risk of falling behind the scholastic achievement [6–8]. The prevalence rates of SLD were 4–9% for deficits in reading and 3–7% for deficits in mathematical reasoning [9, 10].

The sensory-based motor disorder is one of the problems affecting movement control through sensory processing, namely, defects in balance and core stability, motor planning, and sequencing movements [11–14]. Neurological soft signs are minor, non-localizing objective abnormalities that assess motor planning and control in relation to the integration of sensory information [15]. Those soft signs might be clear early in life and disappear as the child's motor and sensory systems become more regulated [16–18]. A debate still exists about the relationship between neurological soft signs and cognitive skills, especially in children with cognitive or academic challenges [19–21].

Therefore, the purposes of the current study were to evaluate the motor and sensory problems in children with SLD and determine the profile of different types of SLD.

Subjects and methods

Participants

Students of both sexes from grades 4, 5, or 6 of elementary governmental schools in Giza, Egypt were selected to participate in this study. Their age ranged from 9 to 13 years and they attended school regularly. Children who used visual or hearing aids, exhibited signs of attention deficit hyperactivity disorder, or presented musculoskeletal disorders in upper limbs such as bone deformities were excluded from the study.

Procedures

Selection stage

Children who failed in 3 periodical exams in reading, writing, and/or mathematics were selected.

Screening stage

Raven's Progressive Matrices test was used to screen the children. It is a valid and reliable test to measure the intellectual level of subjects aged 8–65 years. Raven's Progressive Matrices test is a figure test, based only on visual (not verbal) information (Figure 1) [22].

Diagnosis stage

The children who had IQ ≥ 90 (Figure 1) were tested with the Fathi al-Zayyat battery [23]. It is a valid and reliable stan-

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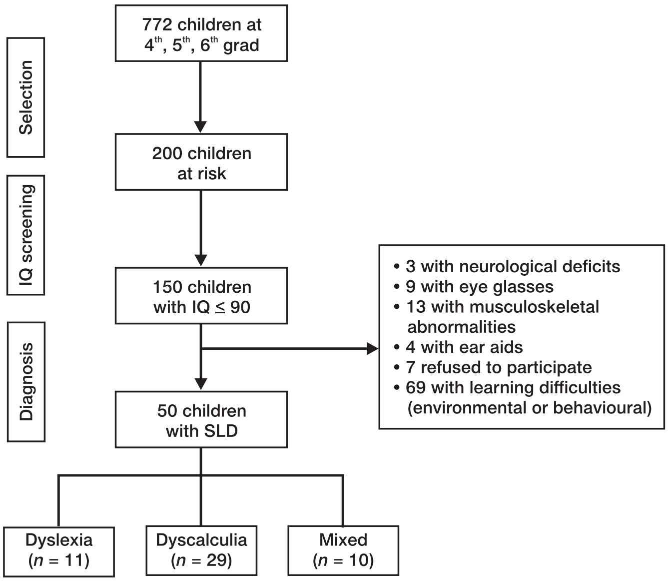

IQ – intelligence quotient, SLD – specific learning disability

Figure 1. Participants flow chart

dardized criterion reference test detecting and diagnosing SLD. The battery includes measures for disturbances of cognitive processing (attention, visual perception, auditory perception, motor perception, and memory), and 3 measures for disabilities in academic learning (reading, writing, and mathematical reasoning). Each measure includes 20 items describing the behaviour patterns associated with learning disabilities in a specific field. A score of ≥ 40 indicates a learning disability. The sequential severity increases with the score.

The participants' sensory-based motor problems (typical and associated with SLD) were screened with the Quick Neurological Screening Test-2 (QNST-2). QNST-2 is a standardized assessment test and a well-validated tool with high sensitivity (97%) and specificity (84%), applied in individuals aged from 5 years to geriatric subjects [15]. It comprises 15 subtests, based on routine neurological examination and developmental scales. It can be scored by categorizing the results as severe discrepancy (with maximum total test scores that can exceed 50), moderate discrepancy (with maximum total scores of 26–50), or normal range (with maximum total scores of 25 or less). QNST-2 required no more than 20–30 minutes as no special materials were needed (apart from a pen, table, chair, and a large room in a relatively quiet testing environment).

Statistical analysis

The descriptive statistics of mean, standard deviation, frequencies, percentages, and confidence interval were utilized in presenting the demographic and clinical data of the subjects. The sample size was calculated with the StatCalc software (Epi Info, version 7.0.8.3 for MS Windows; CDC, USA, 2011). Setting alpha at 0.05 and 2.5% as a maximum accepted error yielded 99% power. The Kruskal-Wallis test was used to differentiate between dyscalculia, dyslexia, and mixed types of SLD. The level of significance for all statistical tests was set at $p < 0.05$. All statistical measures were performed with the Statistical Package for the Social Sciences (SPSS), version 25 for Windows (IBM SPSS, Chicago, IL, USA).

Ethical approval

The research related to human use has complied with all the relevant national regulations and institutional policies, has followed the tenets of the Declaration of Helsinki, and has been approved by the Ethics Committee of the Faculty of Physical Therapy, Cairo University (approval No.: P.T.REC/012/001761) and by education administration.

Informed consent

Informed consent has been obtained from the parents of all children included in this study. The written informed consent has been approved by Directorate of Education, Cairo governorate.

Results

The mean ± standard deviation of age of all children was 11.66 ± 0.86 years. There were 363 (47%) boys and 409 (53%) girls (Table 1). The percentage of learning disabilities in the selected sample was higher for grade 4 and 6 than for grade 5. The descriptive score of QNST was moderate discrepancy in 82% of all types of SLD and normal range in 18% of SLD (Table 2). There were significant differences in all items of QNST when comparing children with SLD with typical peers ($p < 0.05$) except the left-right discrimination item ($p > 0.05$) (Table 3). Regarding the results of QNST within SLD subtypes (dyscalculia, dyslexia, and mixed types), there were significant differences ($p < 0.05$) in the finger-to-nose test, double simultaneous stimulation of hand and cheek test, stand-on-leg test, and tandem walk test, with chi-square of 8.580, 6.249, 15.965, and 4.587, respectively (Table 3).

Table 1. Basic characteristics of participants

Characteristics	All children	SLD children
Sex (*n*, girls/boys)	409/363	24/26
Age (years)	11.66 ± 0.86 ($\bar{x}$ ± *SD*)	
Grade 4	293	22 (2.85%)
Grade 5	247	16 (2.07%)
Grade 6	233	20 (2.59%)

SLD – specific learning disability

Table 2. Descriptive data of Quick Neurological Screening Test

Score of Quick Neurological Screening Test		
Moderate discrepancy	dyscalculia	24 (82.8%)
	dyslexia	9 (81.8%)
	mixed	8 (80%)
Normal	dyscalculia	5 (17.2%)
	dyslexia	2 (18.8%)
	mixed	2 (20%)

Discussion

The current study aimed to evaluate the sensory-based motor deficits in children with SLD, which is a chronic condition. SLD persists in adulthood and becomes a more complex problem, so early detection of this disorder is of paramount importance. Although the procedure is vital, there are many

Table 3. Comparison of mean values of QNST for typical and SLD children

QNST	Between groups		*t*	Within different types of SLD	
	Typical ($\bar{x} \pm SD$)	SLD ($\bar{x} \pm SD$)		Chi-square	Sig.
Hand skills	0.460 ± 0.5035	1.640 ± 0.7494	9.242*	0.580	0.748
Figure recognition and production	0.000 ± 0.000	3.900 ± 1.0152	27.165*	1.051	0.591
Palm form recognition	0.120 ± 0.3283	1.900 ± 0.6776	16.716*	1.189	0.552
Eye tracking	0.240 ± 0.4314	0.800 ± 0.4041	6.699*	8.343	0.15
Sound patterns	1.120 ± 0.5206	6.020 ± 0.4281	51.406*	5.442	0.066
Finger to nose	0.000 ± 0.000	0.720 ± 1.0506	4.846*	8.580	0.014*
Thumb and finger circle	0.000 ± 0.000	0.820 ± 1.7692	3.277*	5.709	0.058
Double simultaneous stimulation of hand and cheek	0.340 ± 0.4785	2.080 ± 2.0187	5.931*	6.249	0.044*
Rapidly reversing repetitive hand movements	1.000 ± 0.0000	2.920 ± 1.0660	12.736*	0.840	0.657
Arm and leg extension	0.340 ± 0.4785	4.920 ± 1.7939	17.444*	0.021	0.989
Tandem walk	0.000 ± 0.000	1.460 ± 1.7286	5.972*	4.587	0.101
Stand on leg	0.220 ± 0.4185	1.580 ± 1.3415	6.843*	15.965	0.0001*
Skip	1.000 ± 0.000	2.440 ± 0.8122	12.537*	2.719	0.257
Left-right discrimination	0.180 ± 0.3881	0.260 ± 0.4431	0.960	6.210	0.045*
Behavioural irregularities	0.180 ± 0.3881	2.000 ± 0.000	33.161*	0.000	1.000
Sum	5.200 ± 1.3553	33.460 ± 5.9357	32.821*	1.260	0.533

* significant
QNST – Quick Neurological Screening Test, SLD – specific learning disability

obstacles. These issues are related to mainstream schooling problems and public awareness so the affected children are reliably diagnosed after starting formal education. Owing to the lack of a standardized objective tool for early diagnosis of children with learning disability, the developmental and neurological assessment might help in early detection of those children because 85% of brain development occurs before the 5th year of age. In the present study, the percentage of SLD was 6.47%, and the percentage of dyscalculia, dyslexia, and the mixed type was 3.75%, 1.42%, and 1.29%, respectively, which is consistent with the prevalence reported by Moll et al. [9]. The percentage of boys equalled 7.16% and was greater than the percentage of girls (5.87%); this comes in agreement with observations by Sousa et al. [24], who attributed the higher rates in boys than in girls to biological factors as the corpus callosum is much thicker in girls so girls are better at using and connecting both hemispheres in cognitive processes. Others believe that the main reason results from bias in referral as male learning difficulties often coincide with other problems: boys are more active than girls, causing discomfort to their teachers [25, 26].

In the current study, dyscalculia and dyslexia were evaluated separately and affected 3.75% and 1.42% of the whole sample, respectively. Dysgraphia, not presented alone, was always combined with dyscalculia and/or dyslexia. These results differ from those obtained by Kovas et al. [27], who reported reading, writing, and mathematics disorders in 3.3%, 5.7%, and 1.8%, respectively, of 337 children. Also, Shah et al. [28] observed reading, writing, and mathematics disorders in 7.47%, 1.70%, and 1.07% of the participants, respectively. The lower reading problems percentage could be ascribed to the good phoneme-grapheme harmony of the Arabic language, making it easy to write and read; reading difficulties are seen at higher rates in languages with poor phoneme-grapheme harmony [29].

The presented findings indicate that 82% of children with learning disabilities have a moderate discrepancy of neurological signs scoring, which indicates problems in motor and sensory development. Westendorp et al. [21] found that children with learning disabilities showed delays in motor skills in the form of neurological soft signs throughout the elementary school years. Also, these results corroborate the outcomes of studies by Padhy et al. [10] and Maehler et al. [30], who mentioned that children with learning disabilities exhibited impaired visual memory, gross motor coordination, and visual-motor skill domains, as well as presented specific deficits in working memory functions.

The distribution of several types of SLD was related to grades, sex, and some subtests of neurological soft signs, such as the finger-to-nose test, double simultaneous stimulation of hand and cheek test, stand-on-leg test, and tandem walk test. These results might be due to deficits in working memory which are associated with the tasks of motor coordination [31]. As SLD children show a lack of attention and concentration, they depend on feedback during movement more than on the feedforward strategy. Suhaili et al. [32] concluded that children with SLD had problems in the internal representation to preplan and expect the necessary motor sequences as tasks require considerable accuracy, good understanding, and good reaction time. Therefore, they were below average in the development of balance and coordination because of problems in executive functions enabling to plan the movement through interaction of the motor areas in the brain with sensory processing areas in the parietal lobe, basal ganglia, and cerebellum [11, 33]. Also, Watson et al. [34] indicated that students with learning disabilities often exhibited significant problems in executive functions, which include working memory operations (updating), inhibition of impulses (inhibiting), mental set or task shifting, and coordinating information in simultaneous mental activities. In turn, Okuda and Pinheiro [35] and Siqueira and Gurge-Giannetti [36] reported that students with learning difficulties presented an age-matched performance in global motor activities as strength, agility, and body coordination when compared with their expected performance. Vuijk et al. [37, 38] mentioned that children with borderline intellectual disability had obvious fine motor problems as compared with their normative peers and the degree of intellectual impairment was associated with the performance of manual dexterity, ball skills, and balance skills. In line with previous findings, Haapala et al. [39], who tested static balance by standing on one leg, observed that there was no effect of academic performance on balance deficits in children with learning disabilities. The results of the current study emphasize the necessity of early identification of children with poor motor performance and constructing rehabilitation programs to improve their motor capabilities and related academic skills during the first school years.

Conclusions

SLDs are better viewed as an umbrella including not only poor academic achievement but also multiple sensory and motor phenomena. In other words, to improve the lifestyle of those children for better coping with everyday activity, tailored physical and occupational therapy programs could be more beneficial than focusing only on academic performance. During the past decade, the understanding of learning disability has been a national consensus in Egypt. However, it is a tremendous challenge to identify and diagnose learning disabilities to help children and parents in remedial solutions. The findings of the current study may be of value for using neurologic assessment as a method of early detection. We recommend further studies to evaluate the validity and reliability of such a modality and to follow up children with learning disabilities to measure the success of the undertaken interventions.

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Disclosure statement

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Conflict of interest

The authors state no conflict of interest.

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