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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 have neurological risks of motor and sensory processing. Evaluation of such a group might help in early identification of their deficits even before early adolescence. To evaluate sensory and motor problems in children with different types of specific learning disabilities.
Methods. A cross-sectional study was performed on students of 4th, 5th, and 6th grades in governmental schools, Cairo, Egypt. 200 children with poor scholastic achievement were screened by intelligent quotient test (The Raven's Progressive Matrices). The learning disabilities were evaluated by Fathi al-Zayyat battery. Then Quick neurological screening test was used to evaluate motor and sensory problems.
Results. Fifty children out of 772 screened children were confirmed to have learning disabilities (29 dyscalculia, 11dyslexia, and 10 mixed), which represented 6.47% of the sample. Also neurological signs were positive in all children with specific learning disabilities while 82% of them were below average.
Conclusions. The study proposed 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 process. Finger to nose test, double simultaneous stimulation of hand and cheek test, stand on leg test, and tandem walk test are associated tests with the type of SLD either dyscalculia, dyslexia or mixed were:
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 impaired; such as in reading(dyslexia), in writing (dysgraphia), and or in mathematical reasoning skills (dyscalculia) during formal years of schooling [1, 2]. The biological causes of SLDs are innate predispositions with evidence that supports reading and mathematics disorders have a common genetic etiology [3, 4]. The intellectual, emotional, visual, hearing, motor, or socioeconomic disturbances weren't the causes of SLD [5]. It is difficult yet 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 mathematics [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 (NSS) 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 NSS and cognitive skills especially for 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 its profile in different types of SLD.

Subjects and methods

The students from elementary governmental schools in Giza, Egypt were selected to participate in this study. They ranged in age from 9 to 13 years from both sexes at fourth, fifth, or sixth grades and they should attend school regularly. The children had the following criteria: use of visual or hearing aids, signs of attention deficit hyperactivity disorder and musculoskeletal disorder in upper limbs such as bone deformities, they were excluded from the study. The study was approved by the Ethical and Research Committee of faculty of physical therapy, Cairo University (no: P.T.REC/012/001761). The informed written consent was approved by directorate of education, Cairo governorate. The parents of selected children signed the consent after they were informed about the study and its objectives.

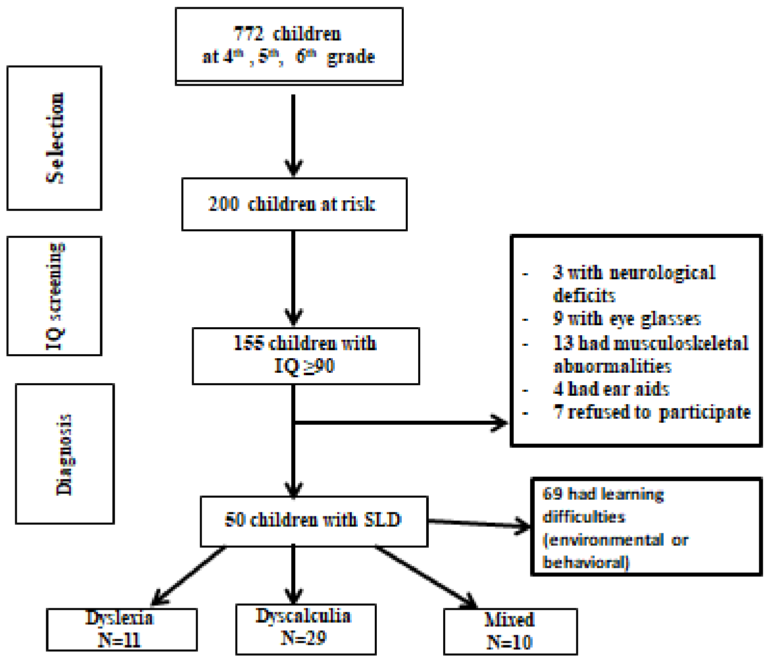
Procedures

Selection stage

The children who fail in three periodical exams of reading; writing and or mathematics subjects were selected.

Screening stage

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



IQ – intelligent quotient, SLD – specific learning disability

Figure 1. Participants flow chart

Diagnosis stage

The children who had IQ ≥ 90 (Figure 1) were tested by Fathi al-Zayyat battery [23]. It is a valid and reliable standardized criterion reference test detecting and diagnosing SLD. That includes

measures for cognitive processing disturbances (attention, visual perception, auditory perception, motor perception, and memory), and three measures for academic learning disabilities (reading, writing, and mathematics). Each measure includes 20 items describing the behavior patterns associated with learning disabilities in a specific field. The student whose score is ≥ 40 grades has a learning disability. The sequential severity is increasing whenever the grade has increased.
Sensory-based motor problems in children (typical and with SLD) were screened by 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%), for an individual's age from 5 to geriatric [15]. It comprises 15 subtests, based on routine neurological examination and developmental scales. It can be scored by categorizing resulting scores as SD (severe discrepancy, with maximum total test scores that can exceed 50), MD (moderate discrepancy, with maximum total scores from 26 to 50) or NR (normal range score, with maximum total scores of 25 or less). This test required no more than 20–30 minutes as with no special materials needed (apart from a pen, table, chair and a large room in a relatively quiet testing environment).

Statistical analysis

Descriptive statistics of mean, standard deviation, frequencies, percentages and confidence interval (CI) were utilized in presenting the demographic and clinical data of the subjects. Sample size was calculated using 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 with power 99%. 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 through the statistical package for social studies (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 before starting our study (no: P.T.REC/012/001761), then it was approved by education administration.

Informed consent

Informed consents have been assigned from parents of all children involved in this study.

Results

The mean ± SD of age of all children was 11.66 ± 0.86 from both sexes as boys were 363 (47%) and girls were 409 (53%) (Table 1). Percentage of learning disability in selected sample increased at 4th grade and 6th grade than 5th grade. The descriptive score of QNST is moderate discrepancy in 82% of all types of SLD and normal average in 18% of SLD (Table 1). 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 2). Regarding the results of QNST within SLD subtypes (Dyscalculia, dyslexia and mixed types), there were significant difference ($p < 0.05$) on finger to nose, double simultaneous stimulation of hand and cheek, stand on leg, and tandem walk with chi-square 8.580, 6.249, 15.965, and 6.210 respectively (Table 3).

Table 1. Basic characteristics of participants

	All children	SLD children
Sex Girls/ Boys	409/363	24/26
Age (years)		11.66 ± 0.86($\overline{X}$ ± 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. Comparison of mean values of QNST for typical and SLD children

QNST	Between groups		t-value	Within different types of SLD	
	Typical $\overline{X} \pm SD$	SLD $\overline{X} \pm SD$		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	.960	6.210	0.045 *
Behavioral 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, SLD – specific learning disability, QNST – quick neurological screening test

Table 3. Descriptive data of quick neurological screening test (QNST)

Degree of QNST		
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%)

* significant

Discussion

The current study aims to evaluate the sensory-based motor deficits in children with Specific learning disability (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. Despite such a vital procedure, there are many obstacles. These issues are related to mainstream schooling problems and public awareness so those children are reliably diagnosed after starting formal education. Due 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 current 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 percentage range of prevalence reported by Moll [9]. The percentage of boys is 7.16%, that is greater than the percentage of girls (5.87%) which comes in agreement with Sousa [24] who attributed the higher rates in boys than girls to biological factors as the corpus callosum, is much thicker in girls than boys so girls are better at using and connecting both hemispheres in cognitive processes. While others believe that the main reason results from bias in referral as that male learning difficulties often coincide with other problems as the boys are hyper actives than girls causing discomfort to their teachers [25, 26].

In current study, dyscalculia and dyslexia could be evaluated separately as it represented 3.75% and 1.42% of the whole sample respectively. While dysgraphia didn't present alone and always combined with dyscalculia and or dyslexia. These results are differed from those of Kucian [27], who found that the reading, writing and mathematics disorders were present in 3.3%, 5.7%, and 1.8% respectively of 337 children. Also, Shah [28] concluded that the reading, writing, and mathematics disorders were 7.47%, 1.70%, and 1.07%, respectively. The lower reading problems percentage could be assumed to the good phoneme-grapheme harmony of Arabic language making it easy for writing and reading so that reading difficulties are seen at higher rates in languages having poor phoneme-grapheme harmony [29].

The current findings indicate that 82% of children with learning disabilities have a moderate discrepancy of neurological signs scoring that indicate problems in motor and sensory development. Westendorp [21] found that the children with learning disabilities show delays in motor skills throughout the elementary school years in the form of NSS. Also, these results come in agreement with Padhy [10] and Maehler [30] as they mentioned that children with learning disabilities impair visual memory, gross motor coordination, visual-motor skills domains and exhibit specific deficits in working memory functions.

The distribution of Several types of SLD were related to grades, sex, and some subtests of NSS as finger to nose, double simultaneous stimulation of hand and cheek, stand on leg and tandem walk subtests. These results might be due to deficits in working memory which are associated with the tasks of motor coordination [31]. As the SLD children show a lack of attention and concentration, they depend on feedback during movement more than assuming a feed-forward strategy. Ibrahim [32] concluded that the children with SLD have problems in internal representation to preplan and expect the necessary motor sequences as tasks require considerable accuracy, good understanding, and good reaction time. So, they were below average in development of balance and coordination due to problems in executive functions by which they able 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] showed that the LD students often have evidence significant problems in executive functions which includes working memory operations (updating), inhibitions of impulses (inhibiting), and mental set or task shifting and coordinating information in simultaneous mental activities. While 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 to their expected performance. Also, Vuijk, et al. [37, 38] mentioned that children with borderline intellectual disability had obvious fine motor problems than the normative peers and the degree of intellectual impairment was associated with performance of manual dexterity, ball skills and balance skills. In line with previous findings, Haapala [39] tested static balance by standing on one leg and found that there was no effect of academic performance in children with LD on balance deficits. The findings of the current study emphasize 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

Specific learning disabilities are better viewed as the umbrella including not only poor academic achievement but also multiple sensory and motor phenomena. In other words, to improve lifestyle of those children for a 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 disability 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 need, and follow up the children with learning disability to measure the success of taken interventions.

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Disclosure statement
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Conflict of interest
The authors state no conflict of interest.

Availability of data and materials
Availability of data can be available upon reasonable request.

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