

Dysgraphia

**Peter Chung, MD and Dilip R Patel, MD,
MBA***

Mattel Children's Hospital, University of California Los Angeles, Los Angeles, California, USA and Department of Pediatric and Adolescent Medicine, Western Michigan University School of Medicine, Kalamazoo, Michigan, USA

Abstract

Writing is an important and complex task that typically develops in early childhood. Dysgraphia is a learning disorder in which the individual's writing skills are below the level expected for his or her age and cognitive level. There are a variety of mechanisms by which dysgraphia may occur. It can present in isolation or with other learning or psychiatric disorders, and can often go undiagnosed. Although the diagnosis and management of dysgraphia usually occurs in an educational setting, the primary physician plays an important role in guidance and advocacy, as well as in the surveillance and evaluation of potential co-morbid conditions.

Keywords: Dysgraphia, education, development, disability, learning

Introduction

Johnny is an 8 year old boy who was diagnosed with attention-deficit/hyperactivity disorder last year. He was started on stimulant medication and has been on a stable dose for the past several months with an improvement in on-task behavior. However, at today's visit, Johnny's mother mentions the teachers have noticed he requires an excessive amount of time to complete written work. Johnny's mother says that he is able to focus on his homework well with the stimulant medication, but "he's just a slow and sloppy writer." When you ask Johnny about his work, he says that he hates writing because "it's hard." Johnny's latest report card includes the comment that Johnny "needs to apply him more if he wants to do well in the fourth grade."

Dysgraphia, from the Greek "dys" meaning "impaired" and "graphia" meaning "making letter forms by hand," is a disorder of writing ability. At its broadest definition, dysgraphia can manifest as difficulty writing at any level, including letter illegibility, slow rate of writing, difficulty spelling, and problems of syntax and composition. In

* **Correspondence:** Professor Dilip R Patel, MD, MBA, Department of Pediatric and Adolescent Medicine, Western Michigan University School of Medicine, 1000, Oakland Drive, Kalamazoo MI, United States. E-mail: Dilip.patel@med.wmich.edu

Diagnostic and Statistical Manual of Mental Disorders 5th edition (DSM-5), dysgraphia no longer exists as a separate category but falls under the category of "specific learning disorder (1)."

According to DSM-5 specific learning disorder refers to difficulties in learning and using academic skills, as indicated by the presence of at least one of the following symptoms that have persisted for at least 6 months, despite the provision of interventions that target those difficulties: inaccurate or slow and effortful word reading; or difficulty understanding the meaning of what is read, or with spelling, or with written expression, or mastering number sense, number facts, or calculation; or difficulties with mathematical reasoning (1).

The DSM-5 further specified that, "the affected academic skills are substantially and quantifiably below those expected for the individual's chronological age, and cause significant interference with academic or occupational performance, or with activities of daily living, as confirmed by individually administered standardized achievement measures and comprehensive clinical assessment (1)."

Although the learning difficulties begin during school-age years, they may not be manifest or recognized until later when the complexity of tasks increase. When considering specific learning disorder, underlying other conditions that might be associated with learning difficulties should be carefully ruled out. These include intellectual disability, uncorrected visual or auditory acuity, other mental or neurological disorders, psychosocial adversity, lack of proficiency in the language of academic instruction, or inadequate educational instruction (1).

The specifier of "with impairment in written expression" includes deficits in spelling accuracy, grammar and punctuation accuracy, and clarity or organization of written expression.

The Individuals with Disabilities Education Act (IDEA) regulations revised in 2004 broadly define "Specific Learning Disability" in the following manner (2):

The child does not achieve adequately for the child's age or to meet State-approved grade-level standards in one or more of the following areas, when provided with learning experiences and instruction appropriate for the child's age or State-approved grade-level standards: Oral expression, listening

comprehension, written expression, basic reading skills, reading fluency skills, reading comprehension, mathematics calculation, or mathematics problem solving.

The child does not make sufficient progress to meet age or State-approved grade-level standards in one or more of the areas when using a process based on the child's response to scientific, research-based intervention; or the child exhibits a pattern of strengths and weaknesses in performance, achievement, or both, relative to age, State-approved grade-level standards, or intellectual development, that is determined by the group to be relevant to the identification of a specific learning disability, using appropriate assessments; and the group determines that its findings are not primarily the result of a visual, hearing, or motor disability; mental retardation; emotional disturbance; cultural factors; environmental or economic disadvantage; or limited English proficiency.

Acquired dysgraphia can be seen in patients following brain injury, neurologic disease, or degenerative conditions and is due to a disruption of existing brain pathways that interferes with previously intact abilities. Although this population has provided interesting insights into the brain pathways of dysgraphia, this review will preferentially focus on developmental dysgraphia (i.e. primary difficulty in learning to write). In this chapter, "dysgraphia" and "disorders of written expression" are used interchangeably (3,4).

Writing development

"Writing" can refer to the basic act of producing written letters and words as well as the complex act of planning, organizing, writing, and proofreading a text. It is a complex process that requires the coordination of motor planning and motor execution in addition to brain processes of organization, executive function, and language which work together to constitute the functional writing system (5). In the preschool years, children learn the basic transcription skills necessary for coordinating the visual and motor systems when copying symbols. Typically, children begin learning to write in kindergarten and first grade, with continued development in second grade. In addition to

learning the motor tasks required to write letters, the child must be sufficiently familiar with the language and the associations between words and sounds (6). By third grade, most children have established automaticity with writing, wherein the movements required to write letters have become rote response patterns (7). However, recent research suggests that handwriting can continue to develop and improve well into the third grade, even while automaticity is emerging (8). In general, many teachers in the United States no longer explicitly teach the process of writing letters, which can hinder those children who struggle to master this skill (9, 10).

Writing tasks beyond the early school years require higher-order language processing and executive function to organize, plan, and execute a coherent and cohesive product. Writing a sentence, for example, requires that the child internally generate the statement, segment the statement into sections for transcription, retain these statement sections in memory while writing, and check the completed written statement against the internally generated thought. Writing a paragraph or essay requires planning, organization, execution, and proofreading to ensure that the statements create a coherent argument or thought. If a child has not achieved automaticity in writing by the third grade, he or she is likely to experience greater difficulty as academic expectations require cognitive processing beyond the motor aspects of writing.

On average, children spend up to half of their school day in tasks that require writing, and the development of handwriting has been correlated with academic achievement (11, 12). Automaticity in letter-writing is a good predictor of quality and length of written assignments in elementary, high school, and college; but impairments in any part of the writing process can interfere with a child's ability to produce written language at an age-appropriate level (10, 13-15). Children with dysgraphia may be labeled as "sloppy" or "lazy" by their teachers instead of being correctly diagnosed with a learning disorder (10). Problems with handwriting can affect self-esteem, perception of ability, and relationships with peers (16, 17). The prevalence of difficulties with writing depends on the definitions and parameters, but somewhere between 10-30% of children may experience difficulties with written language, with

boys more commonly affected than girls (10, 16, 18, 19). Problems with handwriting are a common reason for referral to occupational or physical therapy services (8).

Definition, classification and mechanisms

Experts differ on the specific definition and classification of dysgraphia, depending on the presumed etiology of difficulty with written language (20). Berninger and others define dysgraphia primarily as a language processing disorder that excludes the motor component of writing, sometimes called "dysorthography" or "linguistic dysgraphia (10)." The primary mechanism of such dysgraphia results from inefficiency in the verbal working memory from phonologic (word sounds) to orthographic (written letters) memory, also called the "graphomotor loop." This is contrasted with dyslexia, which is thought to be bilateral inefficiency between phonologic and orthographic processes, or the "phonologic loop." Higher-order language processing centers including storage and executive function are also thought to contribute to the presentation of the disorder (10).

Others specialists define dysgraphia primarily by the difficulties which the child experiences in coordinating movements to write letters; testing may show subtle deficiencies in fine motor tasks like finger tapping or differences in grip, force, and stamina (21). These deficits stem from problems with fine motor control, visual-motor perception, and kinesthesia, resulting in slow and/or poorly formed letters and words. This has been referred to as "peripheral" or "motor dysgraphia" (22).

Zoccolotti and Friedmann suggest that the different presentations of learning disorders such as dysgraphia may be due to different underlying causes and mechanisms (23). However, the dichotomy between these conceptualizations of dysgraphia may not be as clear as once thought, as research has suggested an overlap between the language centers, motor coordination, and the development of automaticity. Historically, children with learning disorders such as dyslexia have been noted to have a variety of motor deficits, including finger tapping,

tying shoelaces, walking backward, swimming, riding a bike, and others. Research models have demonstrated that while only orthographic coding skills significantly predict handwriting in children, incorporation of motor planning skills improves the model fit (10). New functional imaging studies have suggested that the cerebellum plays an important role both in automaticity and in language, and a pediatric case study also demonstrated that injury to the cerebellum can result in the presentation of dysgraphia (22, 24). Nicolson and Fawcett have hypothesized the cerebellum plays a role in the development of a neural system over time, and disorders of this system can present in different ways depending on the brain circuits involved and the age of the patient (20). This "neural systems framework" may explain the mechanistic complexity and apparent conflicts seen in the learning disorders literature, although more research needs to be done to validate the model.

Research in genetics and brain function in the etiology of learning disorders is an ongoing field of interest. Aggregation studies have demonstrated a potential genetic basis for the ability to spell, store and process written words, utilize the orthographic loop, and manage executive function tasks. Specific genes implicated include regions on chromosome 6 (a doublecortin domain-containing protein 2 allele), linked to phonemic awareness; and on chromosome 15, linked to poor reading and spelling (25,26). Functional magnetic resonance imaging (fMRI) studies have demonstrated differential brain activation patterns between individuals with learning disabilities and normal controls with correlations evident among family members (25). Future studies may further illuminate the exact mechanisms by which the individual's writing impairment may develop or occur.

Co-morbidities

Dysgraphia may be isolated or may co-occur with other learning disorders, including dyslexia. Depending on the variables studied and the definitions utilized, between 30-47% of children with writing problems also have reading problems. Children may have a history of oral language problems in the

preschool years that have subtle manifestations through deficits of learning and self-regulation (10). Although some argue that the diagnosis of developmental dysgraphia be reserved for children who have isolated impairment in written language, difficulties with written language can be seen in many different neurologic and developmental disorders (15). These include autism spectrum disorder, attention deficit-hyperactivity disorder, developmental coordination disorder, and cerebral palsy, with anywhere from 90-98% of effected children predicted to have difficulty in written expression (11, 27-30). Children with learning disorders also have an increased prevalence of mental health disorders (31). As many researchers and clinicians have suggested, co-morbidity in learning disorders is the rule, not the exception (32). Therefore, a child with suspected dysgraphia should be evaluated for potential underlying co-morbidities, and children with known neurologic or developmental disorders should be monitored for difficulty with written expression.

Red flags

Dysgraphia may manifest in a variety of ways depending on the age at presentation, as neurodevelopment progresses and academic expectations increase. As a disorder of written expression, dysgraphia may affect one or more levels of writing, including handwriting, spelling, and higher-order organizational skills. Given the normal development of handwriting, dysgraphia is seldom recognized before the first grade, although it may also be missed even in the school age child or young adult.

The National Center for Learning Disabilities provides an excellent discussion for dysgraphia warning signs across ages (33). Manifestations of dysgraphia parallel stages of child development, with more concrete "lower order" difficulties giving way to abstract "higher order" difficulties as the child ages. Pre-school children with dysgraphia may present with the following characteristics:

- An awkward grip or body position when writing
- Tire easily with writing (18)

- Avoidance of writing and drawing tasks
- Written letters are poorly formed, inversed, reversed, or inconsistently spaced
- Difficulty staying within margins

In addition to the above characteristics, the school-aged child with dysgraphia may demonstrate the following:

- Illegible handwriting
- Switching between cursive and print
- Difficulty with word-finding, sentence completion, and written comprehension.

Finally, the teenager and young adult with dysgraphia may also present with the following:

- Difficulty with written organization of thought
- Difficulty with written syntax and written grammar that is not duplicated with oral tasks.

At all ages, individuals with isolated dysgraphia may not be as readily noted as children with more obvious learning impairments such as dyslexia.

Diagnosis

The diagnosis of dysgraphia is usually made in an educational setting by professionals including psychologists, occupational or physical therapists, and special education teachers. This is usually part of an assessment towards eligibility for an Individual Education Plan (IEP) under the “Child Find” program (34). The diagnosis can also be made as a part of a private psychological or educational evaluation, although such assessments usually fall outside the coverage of health insurance. Although there is no consensus regarding the criteria for a diagnosis of dysgraphia, one expert recommendation is the following: illegible handwriting; decreased writing speed; discrepancy between verbal IQ and spelling achievement; and processing deficits in orthographic awareness, graphomotor planning, and/or rapid automatic naming (10). Other tests to consider are evaluations of posture, pencil grip, tremor, and

observed writing habits (26). Tests of visual-motor integration such as the Beery Developmental Test of Visuomotor Integration (VMI) may be utilized, although the VMI may not be sensitive enough to serve as an adequate screening tool as it may not capture orthographic-specific difficulties (8, 35). Overall, information collected should originate from multiple sources and may include cumulative, normative, anecdotal, and observed data (33). A key factor in making the diagnosis is documenting the effects of difficulty writing on the child’s ability to access the educational curriculum in the mainstream setting. As dysgraphia may be associated with other impairments in reading or written language, children with suspected dysgraphia should be evaluated for other potential learning problems.

No specific medical work-up is indicated for the diagnosis of dysgraphia. However, the primary physician can assist in this evaluation by investigating potential co-morbid and co-occurring conditions. The child should have a careful neurologic evaluation looking for signs of an underlying condition, such as cerebral palsy or developmental coordination disorder. Semi-structured interviews and/or validated checklists may be used to investigate for co-morbid mood disorders (e.g. anxiety and depression), behavioral disorders (e.g. ADHD), and neurodevelopmental disorders (e.g. autistic spectrum disorders). The primary care physician should be comfortable with the necessary screening procedures, but referrals to subspecialists such as a developmental-behavioral pediatrician, child neurologist, child psychiatrist, or other mental health professionals may be considered for diagnostic conceptualization and therapeutic planning.

Management

In general, when addressing developmental and learning disorders, interventions can be organized by intensity in the following fashion: 1) accommodation, in which the individual is provided with assistive or augmentative strategies to access the general curriculum; 2) modification, in which the individual's tasks and expectations are changed to minimize the impact of their disability; and 3) remediation, in which the individual is provided instruction specific

to his or her disability. Management of dysgraphia is a life-long process that must address the underlying symptoms experienced by the individual at that time; as the manifestations of dysgraphia change with cognitive development and academic expectations, the management must be equally fluid in its approach. The educational system should assess and provide the appropriate support structure in the school setting for the individual's level of disability. In this section, suggested interventions for dysgraphia will be discussed. However clinicians should also remember that co-morbidities including other learning disorders, ADHD, mood disorders, and others should be addressed through additional educational interventions, therapy, and medication. Unfortunately, school systems under the current (IDEA) regulations may fail to provide specific assessments and treatments for individuals with writing difficulties (10).

Accommodations

Providing assistance with accessing the educational curriculum may decrease the stress associated with writing (33). Special writing implements of larger size or with specialized grips may be provided or allowed. Young children with dysgraphia may try papers with raised lines to provide tactile feedback for staying within margins. Individuals with dysgraphia may benefit from the use of tape recorders and spell-checkers in the classroom environment. Additional time may be provided for written assignments, tests, and homework.

Technology advances including voice-recognition software, computer keyboards, and touchpad devices are attractive potential accommodations for individuals with dysgraphia. However, practice with written implements should not be completely abandoned in favor of these devices, as handwritten language still serves an important role in activities of daily living. Moreover, recent fMRI studies suggests that handwritten letters provide a greater stimulus to learning than printed letters (36). Physicians and educators should remember that any accommodations will not directly address any higher-order writing impairments such as planning and organization.

Modifications

The individual with dysgraphia may benefit from modifications to academic expectations around written expression. Teachers may break down large written assignments into smaller assignments or may choose to focus on content or spelling for the grade. Individuals with dysgraphia may have alternatives to written assignments, such as oral reports and presentations. Writing assignments may be reduced in length or complexity (33). In general, in accordance with the “least restrictive environment” detailed in the IDEA, the individual with dysgraphia should be included in a general education classroom unless there are other impairments requiring more specialized instruction.

Remediation

The extent of difficulty the child experiences with different processes of writing should inform steps to remediation, and a response-to-intervention (RTI) model may be utilized for dysgraphia interventions. The RTI model includes a tiered approach to intervention: in tier 1, screening is conducted on all individuals for prevention purposes; in tier 2, supplementary intervention is provided for a smaller group with particular challenges; and in tier 3, individuals who are identified as requiring additional support receive specialized treatment. Expert advisors have already published recommendations and suggestions for general education teachers on how to support good writing habits in the mainstream environment (19). Children who fail to show a response to initial interventions should be “stepped up” to the next tier of intervention, and early intervention produces the greatest gain (15).

In the primary school years, interventions may focus on motor tasks or orthographic tasks; although the literature suggests that a combination approach is the most effective (37). Motor tasks for writing and writing-related activities include playing with clay, drawing in mazes, and tracing letters; fine motor skills may be developed through the use of hand exercises such as rubbing or shaking the hands and finger-tapping tasks. Children should also practice good posture and grip control to establish good habits to

writing. Research-supported orthographic tasks include the use of an instructional method to teach letter writing described by Berninger, in which the child learns all 26 letters with the following steps: 1) studying numbered arrow cues in a sample, 2) covering the letter and visualizing writing the letter, 3) utilizing the numbered cues to write the letter, and 4) comparing the written letter to the sample letter (13, 38). Children may also need to learn to automatically retrieve letters from long-term memory when composing sentences, which can be done through a variety of educational games and activities (39).

In addition to achieving automaticity, children with disorders of written expression may also need additional support in higher-order writing tasks, including planning, organizing, reviewing, and revising. Randomized-control trials have demonstrated that “writing clubs” targeted to children struggling with these skills can improve performance (37). Another validated model is the self-regulated strategy development (SRSD) instruction in text composition, which has been demonstrated to have a lasting and generalized effect (40). This curriculum includes specific instruction on writing and self-regulation strategies while involving children as active collaborators in the process. Children who continue to struggle with writing in middle school and high school may benefit from additional instruction towards the specific tasks needed in composition (37, 41, 42). Computers may provide additional support in decreasing writing stress if handwriting automaticity continues to pose considerable challenges (43).

Role of the pediatrician

The physician can play an important supportive role in the care of the child with dysgraphia. First of all, the physician should assist the child's family in educational advocacy with the school environment, especially if the individual has been stigmatized as “lazy” or “sloppy”. Since the child’s caregivers serve as the direct point of contact with the school, the physician can guide them to make sure the appropriate steps are taken towards diagnosis and management. As children in most studies demonstrated improvement after 20 lessons over

several weeks, the physician can aid the caregivers in advocating for their child if he or she continues to struggle with writing tasks despite initial interventions. Secondly, the physician may provide psychoeducation for diagnostic de-mystification, which may help the child and family learn to confront the diagnosis (see table). The family should be cognizant of stress associated with writing and provide fun, low-pressure writing activities outside of school. Thirdly, the physician should ensure that appropriate screening procedures take place for the evaluation of co-morbidities as detailed earlier in this chapter. Follow-up visits should include screening for secondary mood disorders such as anxiety and depression, which can develop as academic demands increase. Fourthly, although optimal results should include specific orthographic instruction, the physician may consider referral to occupational therapy to supplement improvements in fine motor control. Finally, the physician may point the family to various supplemental resources or parent groups they may wish to investigate (see table).

Conclusion

Writing is a skill developed in early childhood that is vitally important for learning as well as activities of daily living, particularly as academic and environmental demands increase with age. Dysgraphia and disorders of written expression, though relatively common in children, can be mistaken or overlooked by the school and family of the effected individual.

Regardless of the neuromotor or neuropsychiatric mechanisms underlying the manifestation of dysgraphia, prompt diagnosis and intervention is an important function of the primary health care provider. Special attention must also be given to potential or existing co-morbidities that are common to dysgraphia. Child health care professionals must work closely alongside educational and mental health providers to ensure that dysgraphia is appropriately addressed.

Table

Name	Description	Web Address
Psychoeducation for Parents		
Understanding Dysgraphia: Fact Sheet	Published by the international dyslexia foundation, this 4-page handout provides simple-to-understand information regarding the diagnosis, informed by experts in the field.	http://www.interdys.org/ewebeditpro5/upload/Understanding_Dysgraphia_Fact_Sheet_12-01-08.pdf
What is Dysgraphia?	From the National Center for Learning Disabilities website, this article also links to a variety of internal and external resources for parents and providers.	http://www.ncld.org/types-learning-disabilities/dysgraphia/what-is-dysgraphia
The Importance of Teaching Handwriting	A free resource to aid parents in teaching children handwriting skills, including links about accommodations and modifications in dysgraphia	http://www.readingrockets.org/article/27888/
Strategies for the Reluctant Writer	A free, brief, writing-based intervention that parents can implement at home to help with children who have difficulty writing. Book suggestions are included.	http://www.ldonline.org/article/Strategies_for_the_Reluctant_Writer/6215
TechMatrix	An online database of assistive and educational technology devices that can be searched by content, grade, and educational diagnosis. Includes both software and hardware devices.	http://techmatrix.org/
Handwriting Supplemental Programs		
Zaner-Bloser	Online and hard-copy resources that cover handwriting, writing, reading, and other topics. Several “apps” and writing games available as well.	http://www.zaner-bloser.com/
Handwriting without Tears	A multi-sensory program for children with writing difficulties, including resources for parents and teachers.	www.hwtears.com/
Big Strokes for Little Folks	A program for children who can recognize letters but have difficulty forming them. Includes reproducible worksheets.	Available from multiple sellers, published by Psychological Corp.
Sensible Pencil	A program for use in the school and home to teach writing letters, utilizing eleven basic lines in sequential steps. Includes reproducible worksheets.	Available from multiple sellers, published by ATC Learning Company
Loops and Other Groups	A program for teaching cursive writing via a kinesthetic approach, utilizing motor and memory cues. Includes reproducible worksheets.	http://www.pearsonassessments.com/HAIWEB/Cultures/en-us/Productdetail.htm?Pid=076-1641-890
Support Groups		
Parent Center Network	The resource hub for Parent Training and Information Centers (PTI) that provide assistance on a regional level to parents of children with disabilities	http://www.parentcenternetwork.org
Eye to Eye	A nation-wide mentoring program that partners children with learning and attention problems with high school and college mentors who share the diagnosis	http://eyetoeyenational.org/

References

- [1] American Psychiatric Association. Diagnostic and statistical manual of mental health disorders: DSM-5 (5th ed). Washington, DC: American Psychiatric Publishing, 2013.
- [2] US Department of Education. Topic: Identification of specific learning disabilities. Office of Special Education Programs, 2006. URL: <http://idea.ed.gov/explore/view/p/root,dynamic,TopicalBrief,23>,
- [3] Gubbay SS and de Klerk, NH. A study and review of developmental dysgraphia in relation to acquired dysgraphia. *Brain Dev* 1995;17:1-8.
- [4] Rapcsak SZ, Beeson PM, Henry ML, Leyden A, Kim E, Rising K, Andersen S, and Cho HS. Phonological dyslexia and dysgraphia: Cognitive mechanisms and neural substrates. *Cortex*. 2009;45:575-91.
- [5] Berninger VW and Wolf BJ. Teaching students with dyslexia and dysgraphia. Baltimore, MD: Paul H Brookes, 2009.
- [6] Berninger V, Nielsen K, Abbott R, Wijsman E, Raskind W. Gender differences in severity of writing and reading disabilities. *J Sch Psychol* 2008;46:151-72.
- [7] Feder K and Majnemer A. Handwriting development, competency, and intervention. *Dev Med Child Neurol* 2007;49(4):312-7.
- [8] Overvelde A, Hulstijn W. Handwriting development in grade 2 and grade 3 primary school children with normal, at risk, or dysgraphic characteristics. *Res Dev Disabil* 2011;32:540-8.
- [9] Graham S and Perin D. A meta-analysis of writing instruction for adolescent students. *J Educ Psychol* 2007;99:445-76.
- [10] Berninger VW. Defining and differentiating dysgraphia, dyslexia, and language learning disability within a working memory model. In: Mody M, Silliman ER, eds. *Brain, behavior, and learning in language and reading disorders*. New York: Guilford, 2008:103-34.
- [11] Amundson SJ, Weil M. Prewriting and handwriting skills. In: Case-Smith J, Allen AS, Nuse Pratt P, eds. *Occupational therapy for children*. St Louis, MO: CV Mosby, 1996:524-41.
- [12] Cahill S. Where does handwriting fit in? Strategies to support academic achievement. *Intervent Sch Clinic* 2009;44:223-9.
- [13] Berninger V, Vaughan K, Abbott R, Abbott S, Brooks A, Rogan L, et al. Treating of handwriting fluency problems in beginning writing: Transfer from handwriting to composition. *J Educ Psychol* 1997;89:652-66.
- [14] Connelly V, Campbell S, MacLean M, Barnes J. Contribution of lower order skills to the written composition of college students with and without dyslexia. *Dev Neuropsychol* 2006;29(1):175-96.
- [15] Grizzle KL and Simms MD. Language and learning: A discussion of typical and disordered development. *Curr Probl Pediatr Adolesc Health Care* 2009;39:168-89.
- [16] Feder K, Majnemer A, and Synnes A. Handwriting: Current trends in occupational therapy practice. *Can J Occup Ther* 2000;67:197-204.
- [17] Sassoon R. Dealing with adult handwriting problems. *Handwriting Rev* 1997;11:69-74.
- [18] Kushki A, Schwellnus H, Ilyas F, Chau T. Changes in kinetics and kinematics of handwriting during a prolonged writing task in children with and without dysgraphia. *Res Dev Disabil* 2011;32:1058-64.
- [19] Berninger VW and May MO. Evidence-based diagnosis and treatment for specific learning disabilities involving impairments in written and/or oral language. *J Learn Disabil* 2011;44:167-83.
- [20] Nicolson R and Fawcett A. Dyslexia, dysgraphia, procedural learning and the cerebellum. *Cortex* 2011;47:117-27.
- [21] Tseng M, Chow S. Perceptual-motor function of school-age children with slow handwriting speed. *Am J Occup Ther* 2000;54:83-8.
- [22] Del Castillo MC, Belmonte MJ, Rojas ML, Pino MA, Verdu JB, Rodriguez JM. Cerebellum atrophy and development of a peripheral dysgraphia: a paediatric case. *Cerebellum* 2010;9:530-6.
- [23] Zoccolotti P, Friedmann N. From dyslexia to dyslexias, from dysgraphia to dysgraphias, from a cause to causes: A look at current research on developmental dyslexia and dysgraphia. *Cortex* 2010;46:1211-5.
- [24] Ito M. Control of mental activities by internal models in the cerebellum. *Nat Rev Neurosci* 2008;9(4):304-13.
- [25] Berninger VW and Richard T. Inter-relationships among behavioral markers, genes, brain and treatment in dyslexia and dysgraphia. *Future Neurol* 2010;5(4):597-617.
- [26] Molfese V, Molfese D, Molnar A, and Beswick J. Developmental Dyslexia and Dysgraphia. In: Whitaker HA, ed. *Concise encyclopedia of brain and language*. Oxford: Elsevier, 2010:485-91.
- [27] Rosenblum S, Livneh-Zirinski M. Handwriting process and product characteristics of children diagnosed with developmental coordination disorder. *Hum Mov Sci* 2008;27(2):200-14.
- [28] Chau T, Ji J, Tam C, Schwellnus H. A novel instrument for quantifying grip activity during handwriting. *Arch Phys Med Rehabil* 2006;87(11):1542-7.
- [29] Martins MR, Bastos JA, Cecato AT, Araujo ML, Magro RR, Alaminos V. Screening for motor dysgraphia in public schools. *J Pediatr (Rio J)* 2013;89:70-4.
- [30] Mayes SD and Calhoun SL. Learning, attention, writing, and processing speed in typical children and children with ADHD, autism, anxiety, depression and oppositional-defiant disorder. *Child Neuropsychol* 2007;13:469-93.

- [31] Vedi K, Bernard S. The mental health needs of children and adolescents with learning disabilities. *Curr Opin Psychiatry* 2012;25(5):353-8.
- [32] Kaplan BJ, Dewey DM, Crawford SG, Wilson BN. The term comorbidity is of questionable value in reference to developmental disorders: data and theory. *J Learn Disabil* 2001;34:555-65.
- [33] National Center for Learning Disabilities (NCLD). URL: <http://www.ncl.org/>.
- [34] Wright P, Wright P. Child find, 2008. URL: <http://www.wrightslaw.com>
- [35] Beery KE, Buktenica NA, Beery NA. Beery-Buktenica Developmental Test of Visual-Motor Integration, 6th ed. Minneapolis, Mn: Pearson, 2010.
- [36] Longcamp M, Hlushchuk Y, Hari R. What differs in visual recognition of handwritten vs. printed letters? An fMRI study. *Hum Brain Mapp* 2011;32:1250-9.
- [37] Berninger VW, Rutberg JE, Abbott RD, Garcia N, Anderson-Youngstrom M, Brooks A, et al. Tier 1 and Tier 2 early intervention for handwriting and composing. *J Sch Psychol* 2006;44:3-30.
- [38] Graham S, Berninger VW, Abbott RD, Abbott SP, Whitaker D. Role of mechanics in composing of elementary school students: A new methodological approach. *J Educ Psychol* 1997;89(1):170-82.
- [39] Berninger V and Abbot S. PAL research-supported reading and writing lessons and Reproducibles. San Antonio, TX: Pearson Assessment, 2003.
- [40] Graham S, Harris KR. Students with learning disabilities and the process of writing: A meta-analysis of SRSD studies. In: Swanson HL, Harris KR, Graham S, eds. *Handbook of learning disabilities*. New York: Guildford, 2003:323-44.
- [41] Chenault B, Thomson J, Abbott RD, Berninger VW. Effects of prior attention training on child dyslexics' response to composition instruction. *Dev Neuropsychol* 2006;29(1):243-60.
- [42] Berninger VW, Winn WD, Stock P, Abbott RD, Eschen K, Lin SJ, et al. Tier 3 specialized writing instruction for students with dyslexia. *Read Writ* 2008;21:95-129.
- [43] Alamargot D and Chanquoy L. *Through the models of writing*. Dordrecht, The Netherlands: Kluwer Academic, 2001.

Submitted: January 10, 2014. *Revised:* February 05, 2014.
Accepted: February, 08, 2014.

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.