

Feature Article

Improving handwriting without teaching handwriting: The consultative clinical reasoning process

Rhoda P. Erhardt¹ and Vickie Meade²

¹379 Snowshoe Court, Maplewood and ²Vickie Meade Therapy Services, 2360 Como Avenue, St. Paul, Minnesota, USA

Background and Aim: Children who have difficulty with handwriting are often referred for occupational therapy. This case report describes a dynamic intervention process and consultative relationship between an occupational therapist and physiotherapist, meeting the needs of an adolescent with handwriting problems.

Methods and Results: Examples are given of the collaborative clinical reasoning process, problem-solving strategies, and ongoing adaptation of activities, materials, and equipment, leading to moderate improvement in handwriting and significant improvements in school reports and athletic competence, maintained for 6 years.

Conclusion: Clinical decisions for selecting and modifying intervention techniques can be derived from assessment of occupational performance areas and performance components (underlying motor, sensory, and perceptual deficits interfering with the production of legible handwriting), within relevant performance contexts.

KEY WORDS case report, decision-making, handwriting, home programs, paediatrics.

Introduction

Handwriting is an important skill for school-aged children who need to produce fluent and legible writing for expressing, communicating, and recording ideas. Children who find handwriting difficult cannot always finish assignments on time, may try to use as few words as possible, and most importantly, when focusing on the mechanical aspects of writing, cannot

attend to cognitive content (Graham & Weintraub, 1996; Karlsdottir & Stefansson, 2002; Tseng & Cermak, 1993). Thus, inadequate handwriting can impair academic performance, an important occupation of childhood, adolescence and adulthood (Bergman & McLaughlin, 1988). Effective solutions require creativity in service delivery and intervention options.

Literature review

The foundational prerequisites for efficient, legible handwriting are generally assumed to be visual-perceptual-motor components, that is, the integration of gross motor, fine motor, and oculomotor skills (Kephart, 1971):

Gross motor skills refer primarily to the postural control needed for handwriting: a good base of support in sitting, with hips at 90 degrees and feet stabilised on the floor, good pelvic and spinal alignment, cervical control for downward visual gaze, and shoulder integrity for arm and hand control (Amundson, 1992; Benbow, 1995; Boehme, 1988; Erhardt, 1992). Many children with low postural tone need to exert more effort to maintain upright posture against gravity. Their handwriting often reflects light pencil pressure and deterioration of performance caused by fatigue over time (Gajraj, 1982). Deficits in motor control and perception are usually diagnosed between 5 and 8 years of age, more frequently in boys, and most of these children still show persisting problems affecting many everyday activities, including sports, in their teenage years (Christiansen, 2000).

Fine motor skills of finger dissociation and grading of muscle activity during pencil grasp must be coordinated with fixation at wrist, elbow, and shoulder (Ziviani, 1987). Slow, hesitant, illegible handwriting and low academic work output has been correlated with uncoordinated finger movements (Levine, Oberklaid & Meltzer, 1981).

Oculomotor skills involve: (i) basic motor control of the extraocular muscles (Erhardt, 1990; Hansen, 1988);

Rhoda P. Erhardt MS, OTR/L, FAOTA; Private Practice, Consultant in Paediatric Occupational Therapy. Vickie Meade MPH, PT; Vickie Meade Therapy Services.

Correspondence: Rhoda P. Erhardt, 2379 Snowshoe Court, Maplewood, Minnesota 55119, USA. Email: rperhardtdp@att.net

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(ii) visual perception, the ability to organise and interpret what is seen (Amundson, 1992); and (iii) visual-motor maturation, the ability to integrate the visual image of letters or shapes with the appropriate motor response (Beery, 1997; Maeland, 1992; Tseng & Murray, 1994). Several authors feel that basic shapes should be mastered before a child begins to learn handwriting (Beery; Lindsey & Beck, 1984; Taylor, 1985). Visual motor integration skills were found to be significantly related to academic performance as measured by teachers' ratings of reading, maths, and writing (Hammerschmidt & Sudsawad, 2004; Kulp, 1999).

A survey to determine assessment and treatment approaches commonly used by occupational therapists for children exhibiting handwriting and related fine motor difficulties revealed that a majority evaluated gross/fine motor and perceptual skills, motor planning, quality of movement and sensory functioning for this population. The therapists most often used the Developmental Test of Visual Motor Integration (VMI) (Beery, 1997), Bruininks-Oseretsky (Bruininks, 1978), and Test of Visual Perceptual Skills (Gardner, 1982), rather than standardised handwriting assessments. All used an eclectic treatment approach, with sensorimotor components most frequently utilised (Feder, Majnemer & Synnes, 2000).

The Sugden and Chambers (1998) literature review of intervention methods divided the approaches into two broad categories: (i) process orientated; and (ii) task orientated. The process approach, which is most often used by specialists such as therapists, pinpoints the underlying processes, which have not developed adequately, but are necessary for skill acquisition and successful performance. The task approach, usually used by teachers or parents, focuses on direct teaching and generalisation of the skill (Jongmans, Linthorst-Bakker, Westenberg & Smits-Engelsman, 2003). In other words, the process approach focuses on the actual impairment, while the task approach addresses the functional limitation (World Health Organization, 1997). However, these approaches are not exclusive. The complex nature of children's difficulties frequently lead interventionists toward eclectic and multidisciplinary solutions.

Case description

This case report describes a 13-year-old named Matt with learning problems including illegible handwriting, losing homework, inability to finish timed assignments with the rest of the class, visual fatigue during close work, distractibility, difficulty in sports, and general disorganisation at home and school. His grades were consistently C's and D's, but he did not qualify for special education or related services, according to United States federal law, Individuals With Disability

Act amendments (U.S. Department of Education, Office of Special Education Programs, 1997).

His parents were both very concerned about his academic and athletic performances, his sensitivity to criticism, and his expressed feelings of failure (Skinner & Piek, 2001). They described his activity level as just like his father, a low-key accountant, who stated that although his own motor skills were slow to develop, he became a good athlete in high school and college. His mother, a high-energy exercise instructor, reported that despite excellent gross motor and fine coordination, she often had a left-right confusion and directionality problem. Matt's medical history was essentially normal, although he was a late walker at 15 months and was described by his physician as having low muscle tone. His parents decided to seek a psychological evaluation for possible attention deficit disorder and related learning issues.

Psychological evaluations

The psychologist's diagnosis of Learning Disorder, non-specified, with possible neurological issues of visual perception and visual-motor coordination was based on a battery of psychological and educational instruments, including several subtests of the Developmental Test of Visual Motor Integration (Beery, 1997). The psychologist stated that the subject compensated for these impairments with what he described as superior intellectual function, a score of 122, according to the Weschsler Intelligence Scale for Children, 3rd ed. (WISC-III) (Wechsler, 1991). Attention Deficit/Hyperactivity Disorder was ruled out. Generalised anxiety, negative self-esteem, and anhedonia (sadness) related to his perceived ineffective performance was determined by the Children's Depression Inventory (Kovacs, 1992). Referral was made for an optometric examination to rule out visual deficits.

Optometric evaluations

Standard optometric examination and certain subtests of the Developmental Test of Visual Motor Integration (Beery, 1997) revealed insufficiencies in binocular function (using eyes together comfortably), accommodation (changing and maintaining focus), eye movements (moving eyes accurately from one point to another), visual-motor integration (performing paper and pencil tasks quickly and accurately), and fine motor processing speed (hand coordination). Acuity was minimally affected, however, with a mild astigmatic refractive error for distance. Because the optometrist believed that the subject's handwriting and learning problems in school were more globally motor-based (observed as incoordination in eye muscles also), he referred the student for occupational therapy evaluation.

Occupational therapy interview, referral, and intervention plan

During the initial occupational therapy interview with Matt and both parents, functional problems were discussed, medical and educational histories were reviewed, and clinical observations of posture and movement were documented.

'After I asked Matt to remove his shirt so we could look at his "muscles", I immediately observed significant instability of the shoulder girdle and asymmetrical alignment of the spine, which could certainly interfere with efficient control of head, shoulder, and trunk for precision eye, arm, and hand movements and sports performance. The lack of a stable base for fine motor skill has been associated with handwriting problems (Price, 1986; K. P. Robbins, unpublished data, 1996). In addition, organisational skills are dependent on control of one's own body movements. Despite more than 30 years of paediatric clinical experience, I recognised the need for another expert opinion to facilitate my critical reasoning through collaborative problem-solving (Jensen, Gwyer & Shepard, 2000). I made an immediate referral for a physiotherapy evaluation to a colleague who had a special interest in applying kinesiological principles of balanced muscle work to paediatrics.'

Options for service delivery (methods, duration, and frequency) and definitions of roles (child, family, and therapists) were also discussed, in order to create an effective plan for action (Anderson & Hinojosa, 1984; Lawlor & Mattingly, 1998). Intervention would be designed as a home program, a natural context for practising activities other than handwriting, which attaches meaning, improves motivation, and increases the number of opportunities for learning through practise, according to current theories of motor control and motor learning (Lesensky & Kaplan, 2000; Shumway-Cook & Woolacott, 1995).

The family was asked to participate in an efficacy study with handwriting as the functional skill to be measured. The author of the Minnesota Handwriting Test (J. E. Reisman, unpublished data, 1993; Reisman, 1999) agreed to assist in the design and implementation of the study by independently scoring all samples. After the study received Institutional Review Board approval from the University of Minnesota, the family gave written consent. Handwriting samples (baseline measurements) were taken before occupational and physiotherapy evaluations of component skills were administered and at specific intervals during and after the treatment and maintenance phases (Erhardt & Meade, 2005).

Occupational therapy evaluation

The Purdue Perceptual-Motor Survey was selected for Matt because it was originally developed to provide

practitioners with a tool to identify children who do not possess the perceptual-motor abilities necessary for acquiring academic skills (Roach & Kephart, 1966). Standardised more than 30 years ago, it has been used to test children and young adults with mental as well as physical delays (Neeman, Sawicki & Neeman, 1983). It remains in current use by some practitioners because it is one of the few standardised qualitative measures that detects specific errors in perceptual-motor development, and designates areas and individualised activities for remediation (Erhardt & Duckman, 2005). Test items in the Purdue Perceptual-Motor Survey are grouped into categories of Balance and Posture, Body Image and Differentiation, Perceptual-Motor Match, Ocular Control, and Form Perception. Scores on 22 items provided cross-validation for previous studies on the perceptual-motor attributes of normal school children (Neeman, Sawicki & Neeman, 1989).

This evaluation was first administered at the end of the baseline period, with re-evaluations at the end of the treatment period and at the end of the maintenance period. Matt's gross and fine motor skills showed some developmental delays, related to decreased physical strength (measured in prone extension), postural control, and motor coordination. He achieved a cumulative score of 56 out of a possible 88 points, placing him in the 64th percentile.

Physiotherapy evaluation

The physiotherapy evaluation was administered at the end of the baseline period, with re-evaluations at the end of the treatment period and at the end of the maintenance period. The evaluation involved goniometric measurement of range of motion, grading of strength, and observation of movement patterns of the shoulder for reaching and the legs for single leg stance (Kendall, McCreary & Provance, 1993; Sahrman, 1990, 2002). Evaluation revealed low trunk muscle tone with resulting muscle imbalances at the neck, shoulder, spine, hips, knees and ankles, poor single leg stance and fatigue upon repetition of strength testing. These muscle changes had developed over a long period of time to help generate stability and endurance at each joint to increase control against gravity (Meade, 1998). As Matt attempted more and more difficult functional tasks over the course of his school years, specific muscles had to work harder, and consequently, fatigued more quickly. Matt was unable to coordinate proximal muscles to provide stability at each proximal joint making it difficult to sustain distal work, such as the fine motor tasks of eye and hand control needed for school.

Proximal instability at the shoulders, spine and hips, and muscle imbalances, which pulled Matt's joints

out of normal alignment affected functions important to Matt. For example, Matt needed to control rotation at the shoulder/scapulae to score a goal in basketball. He also needed to rotate and derotate his spine during balance reactions, plus hip rotation to stand on one leg for running during sports.

Intervention plan

The occupational therapy home program was implemented by the parents, 30–45 min per day, 5–7 days per week, and supervised every 2 weeks by the occupational therapist for 5 months. The physiotherapist used monthly consultation to create and supervise the home program with a specific focus on monitoring body alignment and movement patterns. The physiotherapy program was implemented by parents, 5 min per day, 5–7 days per week.

Physiotherapy program

The goal of the 5-min daily physiotherapy program was first, to improve range of motion and postural alignment, and then increase strength and endurance. Efficient postural control and movement requires full elongation of all muscle groups around each joint. Treatment began with movements to elongate muscles determined to be shorter in the evaluation, particularly the latissimus dorsi, pectoralis, lumbar extensors, hamstrings, gastroc-soleus complex and intrinsic muscles of the feet. The stronger or shorter muscle must be in a relaxed state before asking the weaker or longer antagonist to generate force. Otherwise the shorter, tenser muscle will contract and inhibit the activity of the weaker muscle (Janda, 1977). The weaker muscles activated were primarily stabiliser muscle groups, particularly serratus anterior, abdominal obliques and gluteus maximus.

As the program progressed over time, Matt's movement patterns were consistently reviewed for motor control, timing of the scapular-humeral rhythm, and hip stability (standing on one leg), making sure that all joints remained in normal alignment both during physiotherapy exercises and during the occupational therapy portion of the program (Cusick & Stuberg, 1992; Forseth & Sigmundsson, 2003). In several instances, movements were changed so Matt could elongate muscles, especially around the shoulder girdle.

Occupational therapy program

The occupational therapist selected approximately 30 appropriate activities from the Visual-Perceptual-Motor Activities Collection, which contains more than 675 activities on 116 pages (Erhardt, 1997, 2003). The first author compiled this collection, used in her clinical practice for more than 35 years, from many resources, including the remedial activities suggested by the

author of the Purdue Perceptual-Motor Survey (Kephart, 1971). Two or three charts were introduced to Matt at each therapy session, with more added for variety as each activity was completed and discontinued. Parents were provided with: (i) activity charts, (ii) copies of the videos; and (iii) progress notes. The few activities described in this article were selected to illustrate the link between intervention and function (what was important to Matt and to his parents), and the inter-relationship between occupational therapy and physiotherapy (chalkboard drawings and handwriting, shoulder/arm control, ball-handling and posture/alignment/balance).

1. The Activity Charts addressed the postural and movement elements of handwriting. An alteration in any of these elements changes the interaction, requiring a differently organised response from the learner, leading to internalisation and generalisation. A fundamental challenge for teaching motor skills is how to expand the variety of strategies a child has for problem-solving processes. The therapist can systematically vary the parameters of a task to encourage variability of practice, as opportunities for errors and corrections facilitate refinement. For example:

- a. The *Chalkboard Activities Charts* contained many different skills of tracing and copying drawings, considered to be precursors to the perceptual-motor elements of writing (Oliver, 1990; Ziviani, 1995). Initial chalkboard work with lines and shapes instead of letters and words excluded much of the cognitive aspects of handwriting, making integration of the motor aspects easier.

- b. The *Eye-Foot Coordination Chart* activities of erasing shapes on the floor surface with a wet sock on the foot while standing helped generalise this task. It was graded with Matt leaning against a railing for support, then without support to challenge his balance and improve single leg stance. Practise under variable conditions is critical to motor learning. A motor program for the execution of an ordered sequence of movements is common across different sets of muscles, as reported by van Galen and Stelmach (1993), who found that handwriting samples produced by the hand were found to be similar to those produced by the leg with a pen taped to the foot.

2. The format of the progress notes provided documentation not only of specific implementation details and ongoing changes, but also the critical reflection inherent in the therapists' thinking process (Buchanan, Moore & van Niekerk, 1998). For example:
Activity: Chalkboard Templates
Response: Matt used excessive shoulder movement to avoid changing the direction of his hand movement.

The shoulder girdle moved as a unit with the arm, which impacted forearm and wrist flexibility.

Recommendations: Techniques for improving dissociation of arm from shoulder will be discussed at the next physiotherapy consultation.

- Another important component of the assessment/intervention model was videotaping of the entire process. Copies of the videos were used to analyse quality of movements, for parent reference during program implementation, and for visual documentation of change. Certain video segments clearly illustrated the collaboration/consultation process for problem-solving: adapting activities, positioning, and materials as this program progressed. For example:

February

OT: 'Matt, will you show us first how you draw a circle on the chalkboard, and then the ball skill you're working on now? I believe it's bouncing and catching 10 times without moving your feet. I'm concerned about the arm and shoulder moving as a unit.'

PT: 'Matt, please take your shirt off so I can watch your shoulders. I am observing that his shoulders are continuing to "wing" during those two activities because they are unstable and he is not using the serratus anterior to lock down the scapulae. That is why you are observing the lack of dissociation of arms from trunk. However, our last exercise was not effective in isolating the serratus anterior, so let's try something different. Matt, will you stand with your back against the wall? Do you feel the wall with your shoulder blade? Now hold your shoulder blade still, bend one elbow to 90 degrees and slide your arm up very slowly. I call this Wall Angels. Don't go too far. Move only at the top of your shoulder ... Now do the other arm. This is easier to learn than the previous movement.'

OT: 'So, keeping the shoulder blades against the wall is the tactile reminder to keep them stationary as his arm moves? He won't have to watch himself in a mirror?'

PT: 'Yes, and by practising this just a few minutes a day, he is strengthening the serratus anterior, which will hold the scapulae in the right alignment and allow just the arm movement needed for the ball skills.'

OT: 'Not only that, it will improve your arm control for our chalkboard activities and your handwriting, Matt.'

March

Mother: 'Matt's been working very hard. He can't wait to show you what he can do.'

PT: 'Great, Matt, you're keeping your shoulder still while moving your arm. Now try moving your arm a little bit higher ... Good! Turn your arm and wrist so that your thumb touches the wall. That will keep the shoulder alignment correct. I can see that is very hard for you and that the tip of the shoulder rotates forward. Let's add another activity to try and stretch the pectoralis muscle ... Work on that for next time, before you work on the Wall Angels.'

OT: 'Matt, let's see if you can bounce the ball 10 times with your back against the wall, keeping that alignment ... Yes! So what do you think is the next step?'

Matt: 'Can I use a real basketball instead of this playground ball, and work on dribbling? I want to get ready for the next basketball game at school.'

Pretest and post-test video stills in Fig. 1 demonstrate the link between kinesiology and function.

Collaborative clinical reasoning process

Collaboration is defined as the act of working together, a process that is maximised when each participant brings to the relationship specific differences as well as similarities of theory and practice. The differences between the educational backgrounds and clinical experiences of occupational therapists and physiotherapists means that their clients will gain from each person's unique perspectives and knowledge. At the same time, their similarities facilitate communication and mutual problem-solving. In this case, the family members' input was crucial to the collaboration

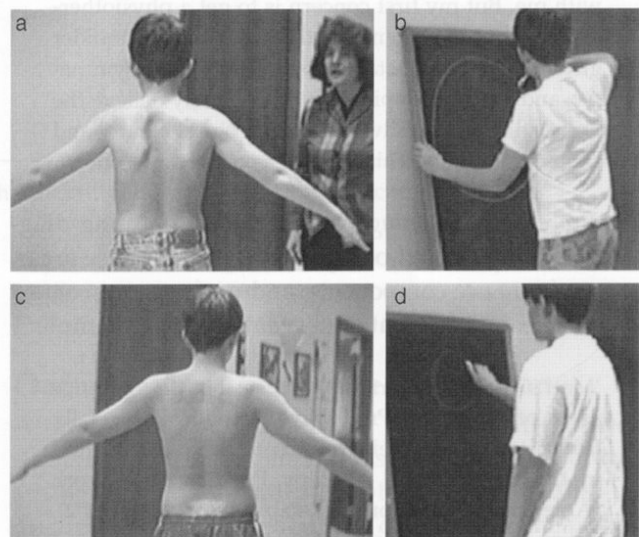


FIGURE 1: Link between kinesiology and function for a 13-year-old boy. (a) Physiotherapy evaluation; (b) occupational therapy evaluation. (c) Physiotherapy re-evaluation and (d) occupational therapy re-evaluation when the boy was 14 years old. This image is from Erhardt and Meade (2005).

process, to keep the focus on what they perceived to be the important issues causing difficulties in activities that were meaningful to Matt. The extremely high compliance throughout the 5-month treatment period was evidenced by the activity chart documentations and the mother's comment 'I know you said we should do them at least 5 days a week, but we are actually doing them every single day'.

Principles of effective clinical reasoning are considered an essential component of most medical and allied health professions (Byrnes & West, 2000). Descriptions of mental operations provide a structure (a thinking frame) to organise and support clinical thinking and reflection (Neistadt, 1996; Neistadt, 1998; Royeen, 1995; VanLeit, 1995):

1. *Narrative reasoning*: encompasses the therapist's, client's, and parents' shared story (how the client's activity preferences will be built into intervention). For example, this was the occupational therapist's thinking process during the first interview:

'Matt's a 7th grade kid with handwriting problems, which concern his parents very much. But he seems more worried about his failures in sports. This referral is not unusual. However, my first meeting with this 13-year-old and his family is unusual. Why? Because I am realising very quickly and with absolute certainty that this particular student and his family will follow through as well as or better than any family I have ever worked with. How do I know that? Perhaps my years of experience gives me the ability to synthesise all my clinical observations today, not only of Matt, but also of his parents, how they interact with him, with each other, and with me. But my first concern is to get a physiotherapist to consult with me on this case. Matt's shoulder girdle looked so unstable, lots of winging, asymmetry, and a possible spinal scoliosis. I truly believe the foundations for handwriting are postural control and shoulder integrity. This must be a collaborative effort.'

2. *Procedural reasoning*: the process of defining diagnostically related occupational performance areas, performance components, and performance context to select appropriate interventions. For example:

'Matt's problems certainly impact his performance areas of Work and Productive Activities, especially Educational, and Leisure Activities, as delineated in the Occupational Therapy Practice Framework (American Occupational Therapy Association, 2002). After evaluating his performance components, I believe his needs are primarily neuromusculoskeletal (range of motion, muscle tone, strength, endurance, postural control, postural alignment) and motor (gross coordination, motor control, fine coordination, visual-motor integration). However, we also need to focus on many of the cognitive components (sequencing,

spatial operations, problem solving, learning, and generalisation) to help him become more organised in every aspect of his life. The interventions we choose will be based on Matt's performance contexts (age and stage of maturation, educational process, home environment and family involvement, peer activities, expectations of his school environment).'

3. *Pragmatic reasoning*: used to consider all the practical issues (political and economic factors) that affect services (treatment environment, therapists' knowledge and experiences, client's social and financial resources, and potential discharge planning). For example:

'It is great that Matt's parents are enthusiastic about implementing the treatment program in their home. I have used this program for many years in different environmental contexts, not only with parents, but with college students, paraprofessionals, or volunteers from community organisations, and sometimes in small groups (Erhardt, 1971). It has been important to constantly incorporate current frames of reference, especially the Model of Human Occupation (Kielhofner, 1995; Kielhofner, 2002) and motor control theory (Bernstein, 1967; Shumway-Cook & Woolacott, 1995). On the basis of my past experience with similar children, I will recommend that we limit the length of the treatment phase to 5 months, giving the parents clear parameters to which they can commit' (Hinojosa *et al.*, 2002).

4. *Conditional reasoning*: used to revise treatment moment to moment, to explore different paths and options to meet the client's current and future needs, and focus on current and future social contexts. Questions we asked ourselves were used for guiding the reflective component of clinical reasoning (Buchanan *et al.*, 1998). For example:
 - a. 'How have we deviated from our original plan? Instead of proceeding step-by-step through activity charts such as Ball Skills, we frequently adapted positioning, skipped certain items, and added others, especially relevant physiotherapy exercises.'
 - b. 'Why did we make these changes? Because certain positions and activity items were either too easy, too difficult, or seemed to promote misalignment.'
 - c. 'How did we make choices for further changes that still related to the family's primary goals of improving Matt's handwriting and athletic skills? We constantly invited input from Matt and his parents.'

Maintenance program

During the treatment period, Matt, his parents, and therapists developed a Maintenance Program Checklist to build awareness about postural reminders into daily routines. For example, when carrying groceries

TABLE 1: Summary of all occupational therapy evaluations: The Purdue Perceptual-Motor Surveys

	Before treatment (13 years)	After treatment (13 years, 6 months)	After maintenance (14 years)
Balance and posture			
Walking board			
Forward	3	4	4
Backward	2	4	4
Sideward	1	3	4
Jumping	3	4	4
Body image and differentiation			
Identification of body parts	3	4	4
Imitation of movement	3	4	4
Obstacle course	4	4	4
Kraus-Weber test	3	4	4
Angels in the snow	3	4	4
Perceptual-motor match			
Chalkboard			
Circle	4	3	4
Double circle	2	3	4
Lateral line	4	4	4
Vertical line	4	4	4
Rhythmic writing			
Rhythm	4	4	4
Reproduction	3	3	4
Orientation	3	3	2
Ocular control			
Ocular pursuits			
Both eyes	2	4	4
Right eye	2	4	4
Left eye	2	3	4
Convergence	2	4	4
Form perception			
Visual achievement forms:			
Form	3	3	4
Organisation	2	3	4

Scoring key: 4, excellent (adequate performance); 3, good (slight difficulty); 2, fair (significant difficulty); 1, poor (inadequate).

(household chores), Matt was advised to keep arms forward, shoulders down and back, instead of elevated and forward. Postural reminders (in the classroom) were: spine straight, feet flat on the floor, and arms supported on desk. Matt should make sure that his golf bag had double straps to avoid asymmetry (sports). In order to sustain that accountability, we asked Matt to continue documenting the date and number of times he participated in each maintenance activity when both therapies were discontinued after 5 months, until the final re-evaluations were administered at the end of the maintenance period 7 months later.

Occupational therapy re-evaluation

After the 5-month treatment period, Matt showed significant improvements in tasks of postural control, strength, and visual-perceptual-motor skills, as documented on the activity charts and measured by the Purdue Perceptual-Motor Survey (from the 70th to the 91st percentile). After the maintenance period, the second re-evaluation indicated that he not only maintained previous gains, but had continued to improve, achieving the 100th percentile (Table 1).

TABLE 2: Summary of all physiotherapy evaluations

	Initial evaluation	After 5 months treatment	After 7 months maintenance
Neck	Hyperextension	Normal	Normal
Spine	C-curve to left	Normal	Normal
Shoulders	Winging; Serratus anterior: Grade 3	One pushup without winging; Serratus anterior: Grade 4	Four pushups without winging; Serratus anterior: Grade 4
Pelvis	Increased lumbar extension, with pain; Abdominals: Grade 3	Normal, no pain Abdominals: Grade 4	Normal, no pain Abdominals: Grade 5
Hip	Glutei: Grade 3	Glutei: Grade 3	Glutei: Grade 4 (right) Grade 5 (left)
Knee	Short hamstrings; Quadriceps: Grade 3, with pain	Short hamstrings; Quadriceps: Grade 4, no pain	Short hamstrings; Quadriceps: Grade 5, no pain
Ankle	Gastrocnemius & dorsiflexors: Grade 3	Gastrocnemius & dorsiflexors: Grade 4	Gastrocnemius & dorsiflexors: Grade 5
Single leg stance	3 s (right)	10 s (right)	30 s (right)

Scoring key: Grade 0, no strength; Grade 1, trace; Grade 2, poor; Grade 3, antigravity full range without resistance; Grade 4, full range with some resistance; Grade 5, full range against full resistance (Kendall *et al.*, 1993). This table is reproduced from Erhardt and Meade (2005) with permission.

Physiotherapy re-evaluation

After the treatment period, Matt showed improvement in postural alignment, strength, and range of motion, with some weakness in postural stabilisers, which fatigued quickly and could certainly affect handwriting. He was asked to continue working on strength through functional activities and sports in his maintenance program. Because all muscles and joints were now in their correct anatomical positions, it was theorised that strength would continue to increase with functional use of the muscles. After the maintenance program, which emphasised correct alignment while lifting and carrying heavy objects at home and during sports, he achieved a normal range of motion, balance, and strength, except in the shoulder and hip abductor muscles, which remained a four out of five grade of strength (Table 2).

Independent evaluations

Psychological and optometric re-evaluations were both administered 3 months after occupational and physiotherapy were discontinued.

Psychological outcomes

The psychological evaluations showed significant improvement (96th percentile compared to 16th percentile 1 year previously) in selected subtests of visual-motor integration as measured by the Developmental Test of Visual Motor Integration (VMI) (Beery,

1997). General performance-anxiety, depression, and self-esteem issues, as measured by the Children's Depression Inventory (Kovacs, 1992) were now within normal ranges instead of 'problematic elevation' (transcribed from the psychologist's videotaped verbal report) (Table 3).

Optometric outcomes

The optometric evaluations showed improved ability to focus (accommodative amplitude) and more efficient visual processing with less effort. Matt also showed significant improvement in selected subtests of visual motor integration, as measured by the Developmental Test of Visual Motor Integration (Beery, 1997), scoring in the 98th percentile compared to being in the seventh percentile 1 year previously (Table 4).

Handwriting outcomes

Handwriting samples taken using The Minnesota Handwriting Test demonstrated strong improvement in alignment and size, and moderate improvement in legibility, form, and spacing. Raw scores from the handwriting samples were graphed by error category for visual inspection of the results. Mean scores were then graphed in the baseline, early treatment, late treatment, and maintenance periods (Erhardt & Meade, 2005). Two of the handwriting samples (one before treatment and one after treatment and maintenance) are presented here for visual inspection (Fig. 2).

TABLE 3: *Psychological evaluations*

Wechsler Intelligence Scale for Children (WISC-III)		
Test (CA: 12 years, 7 months)	Intelligence quotient (IQ)	Percentile
Verbal IQ	121	92
Performance IQ	120	91
Full Scale IQ	122	93
Selected subtests of the Developmental Test of Visual-Motor Integration (VMI)		
Chronological age	12 years, 7 months	13 years, 8 months
VMI Age equivalent	9 years, 6 months	14 years, 0 months
VMI Percentiles	16th percentile	96th percentile

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TABLE 4: *Optometric evaluations*

	Before treatment (12 years, 9 months)	After treatment (13 years, 8 months)
Selected subtests of the Developmental Test of Visual-Motor Integration (VMI)		
VMI	7th percentile	98th percentile
Accommodative amplitude		
OD (right eye)	8.00 diopters	10.50 diopters
OS (left eye)	7.00 diopters	10.50 diopters

Note: Accommodative amplitude should be 13 diopters at age 13 years, according to Donder's Table of Expecteds (Borsh, 1975). This table is reproduced from Erhardt and Meade (2005) with permission.

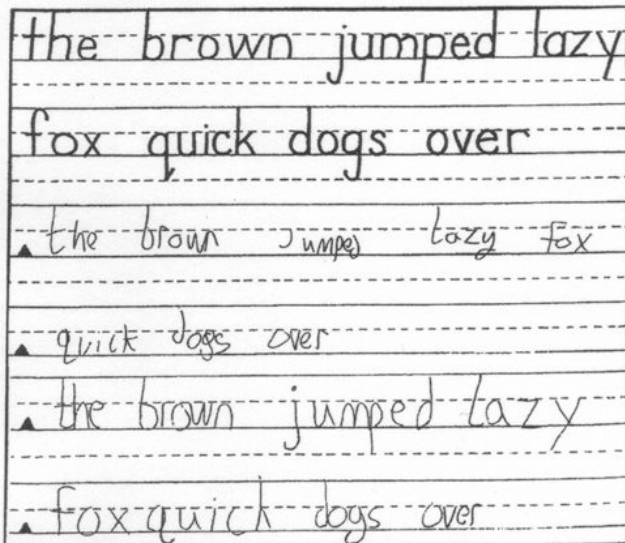


FIGURE 2: *Handwriting samples. Top 2 rows: Model; Middle 2 rows: Before treatment; Bottom 2 rows: After treatment. This image is from Erhardt and Meade (2005).*

Child, parent, and school reports

Matt: 'At school I sit up straight with feet on the floor instead of slumped all the time. My hand doesn't

hurt when I use a pencil now and it doesn't get sweaty. I finally enjoy playing basketball because I can score goals now.'

Mother: 'I thought his handwriting would be perfect, and it certainly is not. But it is easier to read, and we are so happy about his other successes. He does his own homework now instead of dictating it to me to write (or he never got it done). He used to write three or four sentences in his reports, and now he writes three or four pages! His report card grades have gone from primarily C's and D's to A's, B's, and occasional C's. He has more self-confidence, and more willingness to participate in team sports. His Dad is really happy that his grades came up, so he could be accepted into the private high school we wanted (Dad's alma mater).'

The literature reports that children with handwriting problems have benefited from short-term occupational therapy programs, but limited research exists demonstrating positive outcomes in older children, especially those that are maintained after treatment is terminated. From age 13 years to his current age of 20 years, Matt's parents have regularly shared copies of his high school and college reports with his therapists. He has consistently maintained A's and B's, has

been enrolled in honours maths and science classes, and has increased his participation in school and community athletic activities. The unexpected improvement in report card grades may be partially explained by research findings stating that, regardless of content, teachers have been found to assign higher scores to papers with good penmanship. Thus, academic grades may be negatively influenced by less legible handwriting, despite special training aimed at guarding against appearance bias (Graham & Miller, 1980; Sweedler-Brown, 1992).

Discussion and conclusions

The primary purpose of this case report was to describe the dynamic process of the collaborative relationship between an occupational therapist, physiotherapist, and family members to meet the needs of an adolescent with handwriting problems and a diagnosed learning disorder. Within the framework of this process, examples of clinical reasoning and therapeutic modalities demonstrate how the intervention program was designed to achieve improvements in functional performance.

The collaboration/consultation model provided an opportunity for both therapists to empower the parents and their son by including them in that process. Because there was no teaching of handwriting, even a moderate improvement could be attributed to changes in underlying process variables (not only task variables) and in following recognised principles for managing successful intervention programs described by Sugden and Chambers (1998). For example:

- Development of positive relationships and communication between family and professionals results in true family commitment to the program (Cantu, 2003; McGuire, Crowe, Law & Van Leit, 2004). According to the Model of Human Occupation (Kielhofner, 1995), the construct of self-efficacy is an important component of the volition subsystem, 'a sense of control in achieving desired outcomes of behaviour' (p. 43).
- Emphasis on foundational components of handwriting (postural control, whole body function, and organisational skills) and performance components (underlying motor, sensory, or perceptual deficits that were interfering with the production of legible handwriting) (Reisman, 1991) should be within relevant performance contexts.
- Explanations about the purpose of each activity and its relationship to the functional goals and activities that are important to the subject can contribute to higher compliance (Chen, Neufeld, Feely & Skinner, 1999).
- Written charts, progress notes, and videotapes can clarify procedures and provide documentation.

- Careful sequencing and adaptation of activities, materials, and equipment to ensure success can provide motivation through the subject's perception of self-efficacy.
- Integration of treatment principles into daily living activities (maintenance program), provides practise and repetition for successful motor learning.

Significant improvements in visual-perceptual-motor components underlying occupational performance related to improved handwriting were shown by occupational therapy and physiotherapy re-evaluations. Independent psychological and optometric re-evaluations supported those component improvements. In addition, functional results meaningful to the student and his parents, such as higher report card grades and increased athletic competence, were achieved and have been maintained for more than 6 years.

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