



Original Article

Short-term sensorimotor-based intervention for handwriting performance in elementary school children

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Abstract **Background:** Handwriting problems in childhood can have lifelong repercussions, affecting learning and career. Sensorimotor intervention therefore helps to alleviate these problems.

Methods: Thirty-one students (16 boys, 15 girls) underwent Minnesota Handwriting Assessment (MHA) to assess legibility, form, alignment, size, and spacing (the primary variables in this subject) as well as rate. Finally, 10 students (seven boys, three girls) aged 6–8 years (mean age, 77.1 ± 1.45 months) participated in an intervention program. Baseline MHA, Handwriting Proficiency Screening Questionnaire (HPSQ), and grip strength were measured. The same group of students acted as their own controls and were analyzed before the interventions and later after completion of the protocol.

Results: There was a significant improvement in MHA scores for legibility, form, alignment, size and spacing ($P < 0.05$), with the exception of rate. There were also significant changes in legibility, time performance and physical and emotional wellbeing domains in the HPSQ, and grip strength ($P < 0.05$, paired *t*-test).

Conclusion: Short-term sensorimotor-based intervention produced significant improvements in the handwriting performance of elementary school children.

Key words elementary school, grip strength, handwriting, legibility, performance.

Handwriting is an academic skill that allows individuals to express their thoughts and feelings and communicate with others. The skill of handwriting is also referred to as a “graphomotor” skill, including visual–perceptual, orthographic coding, motor planning and execution, kinesthetic feedback and visual–motor coordination.¹ Children spend 31–60% of their classroom time performing handwriting and other fine motor tasks, and difficulty in handwriting can influence academic achievement, which in turn affects self-esteem.^{2–4} Although completing assignments by hand remains a prevalent practice in many elementary schools, an estimated 25–33% of students are struggling to achieve competency in this skill.^{5,6} A total of 12–30% of children fail in the motor learning of handwriting and therefore are considered as poor writers or as having dysgraphia,⁷ namely a learning disability that concerns the mechanical handwriting skill, unrelated to reading or spelling abilities.⁸ Parents and teachers may not be aware of their child’s handwriting problem, which may have lifelong repercussions for the child and affect learning and career.

Richards *et al.* note that handwriting is a “brain-based skill that facilitates meaning-making as writers externalize their cognitions through letter forms, the building blocks of written

words and text”, further supporting the concept that handwriting is not merely a mechanical or motor skill.⁹ Similarly, Christensen suggests that handwriting is not only about training the hand (motor skill); but it is also about how memory and orthographic processes work together to remember the letterforms and translate these figures onto the page automatically.¹⁰

The traditional art of letter writing is declining as rising numbers of children turn to email, text messages and social networking sites. It is frequently alleged that the pen is mightier than the sword, but a recent survey found that less of the student population writes every day. Psychologists and neuroscientists say it is far too soon to declare handwriting a relic of yesteryear. New evidence suggests that the links between handwriting and broader educational development run deep.^{11,12}

Handwriting/fine-motor difficulties are well documented as serious impediments to academic learning for kindergarten and elementary school children. Research suggests that handwriting influences reading, writing,^{13–15} language and critical thinking.¹⁶ Children with writing disorders have a tendency towards lower mathematics achievement, low verbal IQ, and increased attention difficulties, and consistently achieve lower marks compared with controls.^{2,17–19} Handwriting difficulties in children include illegibility and inefficient writing speed. Legibility and performance time are important outcome parameters to assess and define poor handwriting.^{20,21} In addition to legibility and timing deficits, children with dysgraphia

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complain more about fatigue and hand pain, and are unwilling to write and do their homework; these signs represent a category of physical and emotional wellbeing.^{21–24} Therefore, a child's ability to write in a manner that is both legible and efficient, directly affects his or her school performance and academic advancement. Hence, it reinforces the importance of identifying handwriting difficulties as early as possible, both as a preventive and as a corrective aid.

It is common for elementary-school children with handwriting difficulties including legibility problems to receive remedial education from their teacher or be referred to occupational therapy for evaluation and intervention.⁶ The teacher is an important source of information about a child's handwriting. Thus, teachers have been adopted as the main source of information to identify the non-proficient handwriters.^{25–27} Communication with teachers is a decisive element for carry-over of intervention strategies to facilitate student success.²⁸

The common assumption among therapists is that a causal relationship exists between these lower-level processes and handwriting performance, and that remediation of these skills will result in improved handwriting.²⁹ Therefore, occupational therapists (OT) typically classify handwriting difficulties into sensorimotor (SM) and perceptual components in order to identify the foundation skills associated with the functional skill of handwriting. There is empirical evidence regarding the association of performance skills with handwriting, but the contribution of these performance skills is not well understood.^{28–33} SM approaches use some combination of sensory input and motor activities to facilitate the expected normal motor response and promote motor skill development.^{34–37}

Research in the 20th century has led to several important advancements in the area of evaluation of handwriting difficulties, which are categorized as either global-holistic or as analytic evaluations.^{20,38} The Handwriting Proficiency Screening Questionnaire (HPSQ) was designed for use by teachers or therapists to pinpoint handwriting deficiency among school-age children.^{21,39} The Minnesota Handwriting Test was developed to meet the need of OT for an educationally relevant, norm-referenced test that can identify students with handwriting difficulties as well as document treatment effectiveness.⁴⁰ Effectiveness of remedial handwriting intervention programs conducted by OT with positive outcomes were documented,^{28–35} but not much literature is available in the Saudi Arabian context.

The present study will help to identify students in school who have poor handwriting and therefore help to improve overall academic performance. The purpose of this study was to evaluate the additive effects of SM intervention on the child's handwriting. Research questions involved the possible effects of the intervention on specific qualities of handwriting (legibility, form, alignment, size, and spacing) and on speed. Secondary research questions involved possible effects of training in teacher assessment using the HPSQ and grip strength.

Methods

Research design

This prospective, one-group, pretest–post-test experimental design was used to evaluate the effectiveness of an SM intervention. We used a convenience sample of public school classes at the British International School, Riyadh, Saudi Arabia. The research ethics committee of the College of Applied Medical Sciences, King Saud University (CAMS 35–34/35-Ethics Number) and the School Authorities approved the study. Handwriting assessment was carried out before and after intervention.

Sample

Students in two first grade classes for whom English was their first language, but who had no identified educational need, were selected to participate in the study. The parents were informed about the study during student orientation and completed consent forms at the time of the teachers' initial assessment. Thirty-one students (16 boys, 15 girls) were screened using the Minnesota Handwriting Assessment (MHA), which assesses legibility, form, alignment, size, and spacing (the main variables in this study) as well as rate. Twenty students fulfilled the inclusion criteria for performing somewhat below peers or performing well below peers in at least two components of the MHA. Among them, 13 students agreed to participate in the intervention program, later two students left the school, and one student left the study before the actual intervention. Finally, 10 students (seven boys, three girls) aged 6–8 years (mean age, 77.1 ± 1.45 months) participated in intervention program (Table 1). The research plan called for exclusion from the study for any student with direct intervention for handwriting problems prior to the study, and who missed more than two intervention sessions. The schoolteacher administered the HPSQ prior to initiation of the protocol. Handgrip strength was measured using a Jamar hand-held dynamometer (Jamar, Bolingbrook, IL, USA).

Instruments

The MHA was used in the current study as a screening tool and to measure outcome.^{37,40} The near-point copy assessment analyzes Rate, Legibility, Form, Alignment, Size, and Spacing. Performance is then judged and classified as performing like peers (upper 75th percentile); performing below peers (bottom

Table 1 Subject characteristics

Characteristic	Mean \pm SD or n
Age months (n = 10)	77.1 \pm 1.45
Hand dominance Right/Left	8/2
Gender Male/Female	7/3
Ethnicity (Arab/British)	8/2

Table 2 MHA scores for within-subjects factors (Manuscript)

Manuscript (n = 10)	Time	MHA score (Mean ± SD)	F	P-value
Rate	Baseline	20 ±7.77	3.886	0.080 (n.s.)
	Before intervention	21.3±3.31		
	After intervention	27.4±7.94		
Legibility	Baseline	21±8.52	22.965	0.001*
	Before intervention	26.5±7.42		
	After intervention	33.7±0.68		
Form	Baseline	17.50±5.29	61.682	0.000*
	Before intervention	20.80±5.54		
	After intervention	30.80±2.15		
Alignment	Baseline	5.80±6.85	72.610	0.000*
	Before intervention	18.00±4.85		
	After intervention	30.90±4.31		
Size	Baseline	8.20±8.35	66.122	0.000*
	Before intervention	20.20±4.49		
	After intervention	32.20±2.74		
Spacing	Baseline	20.50±8.18	13.183	0.005*
	Before intervention	23.00±5.85		
	After intervention	30.90±3.57		

*P ≤ 0. 05 (repeated-measures ANOVA). MHA, Minnesota Handwriting Assessment; ns, non significant.

Table 3 MHA scores for within-subjects factors (D’Nealian)

Manuscript (n = 10)	Time	MHA score (Mean ± SD)	F	P-value
Rate	Baseline	20.60±6.68	31.954	0.000*
	Before intervention	25.0±7.71		
	After intervention	33.6±1.27		
Legibility	Baseline	26.7±5.58	15.281	0.004*
	Before intervention	27.0±6.18		
	After intervention	33.8±0.42		
Form	Baseline	22.00±5.01	25.175	0.001*
	Before intervention	23.20±4.98		
	After intervention	30.60±1.65		
Alignment	Baseline	8.60±7.98	58.827	0.000*
	Before intervention	20.00±8.69		
	After intervention	29.80±4.94		
Size	Baseline	11.30±8.76	57.168	0.000*
	Before intervention	22.20±9.17		
	After intervention	32.40±1.51		
Spacing	Baseline	25.50±6.67	8.288	0.018*
	Before intervention	25.70±5.36		
	After intervention	31.00±1.76		

*P ≤ 0. 05 (repeated-measures ANOVA). MHA, Minnesota Handwriting Assessment.

5–25th percentile); and performing well-below their peers (bottom 5th percentile).

Test sheets for the MHA are available in both standard manuscript and D’Nealian script style to fit the instructional style of each class. Students copy words from a pre-printed example onto marked lines below the example. The example (“the quick brown fox jumped over the lazy dogs”) includes all letters of the alphabet. The handwriting sample was scored based on specific directions for each category (legibility, form, alignment, size, and spacing) and rate. Each category was scored based on the error rate with a maximum potential score

Table 4 Post-intervention changes in MHA score for Manuscript and D’Nealian style

Manuscript (n = 10)	t	P-value
Rate	−2.141	0.061 (n.s.)
Legibility	−2.951	0.016*
Form	−5.752	0.000*
Alignment	−8.310	0.000*
Size	−10.757	0.000*
Spacing	−4.570	0.001*
D’Nealian (n = 10)		
Rate	−3.459	0.007 (n.s.)
Legibility	−3.374	0.008*
Form	−3.805	0.004*
Alignment	−4.889	0.001*
Size	−10.757	0.000*
Spacing	−2.994	0.015*

*P ≤ 0. 05 (paired-sample t-test). MHA, Minnesota Handwriting Assessment; ns, non significant.

Table 5 Change in HPSQ score and grip strength

Characteristics	Before (Mean ± SD)	After (Mean ± SD)	P-value
HPSQ			
Legibility domain	5.80±3.58	2.90±2.52	0.020*
Time performance	6.00±3.24	4.00±2.49	0.019*
Physical and emotional wellbeing	8.50±6.02	3.10±2.81	0.012*
Total	19.90±9.66	10.00±6.47	0.002*
Grip strength			
DOM grip	17.50±5.89	20.50±5.51	0.024*
NDOM grip	14.00±6.99	18.00±4.22	0.022*

*P ≤ 0. 05 (paired-sample t-test). DOM, dominant; HPSQ, Handwriting Proficiency Screening Questionnaire; NDOM, non-dominant.

of 34. Rate or speed was scored by counting the number of letters completed in 2.5 min.^{37,40}

The HPSQ was used to identify handwriting deficiency among school-aged children and is appropriate for varied academic and clinical purposes. The tool has good internal consistency (α = 0.90). Score test–retest reliability had an intraclass correlation coefficient (ICC) of 0. 84 and ICC inter-rater reliability 0.92.^{21,39} Non-proficient handwriters were classified as having HPSQ score ≥14, and proficient handwriters as having HPSQ score <14.

A calibrated hydraulic hand-held dynamometer, the Jamar hand-held dynamometer, was used to measure isometric grip strength for both the dominant and non-dominant hand.^{41,42}

Procedure

This survey was conducted during March 2014–March 2015. The children (n = 31; 16 boys, 15 girls) from two first grade classes completed the MHA. Students are seated at the appropriate height for their size in a distraction-free environment. A stimulus sheet for both the manuscript and D’Nealian-style handwriting were given to each child after explaining the

directions of the writing process as per the kit guidelines. After evaluating MHA scores, the students who fulfilled the inclusion criteria were chosen to take part in the study ($n = 20$). Parents were informed of the voluntary participation of the students in the sensory intervention program to improve their handwriting skills, by the school authorities. Ultimately, 10 students (seven boys, three girls) agreed to participate in the study. These students were promoted to second grade at the start of the intervention. Baseline HPSQ, MHA and grip strength were measured. The same group of students acted as their own controls, and were assessed before intervention and later after completion of the protocol.

The SM-based intervention group met twice per week (Monday and Wednesday) from 11:45 am to 12:35 pm for 5 weeks during regularly scheduled school hours. These students were given training in separate classrooms. Each 40 min session consisted of 10 min of gross and fine motor warm-up activities,⁴³ followed by 30 min of SM component activities in visual perception, visual-motor integration, proprioception/kinesthesia, and in-hand manipulation.²⁹

The intervention was provided in two small groups in quiet, private rooms at the schools. One OT and a physical therapist with pediatric experience along with a special education teacher were present during the intervention. Therapists were supplied with a toolbox of games, activity worksheets, equipment, and treatment ideas for each factor, as well as the schedule for rotation of activities.²⁹ All the students participated in the initial warm-up session and requested to do all SM activities in random order. The treating therapists and students, however, were permitted flexibility in choosing the activities during each session from the list supplied, and to vary the format, order, and the materials used in the interventions. Therapists and teachers assigned to the stations monitor students and provide specific feedback, support and instruction as needed. The students rotated through the stations in random order to perform the list of activities (Appendix S1) and therapists emphasized performance of all the activities.

Statistical analysis

Data were analyzed using SPSS 22 (IBM Corp, (2013), Armonk, NY, USA) and 95%CI. Descriptive statistics were used for demographic characteristics. The level of significance was set at 0.05. Repeated-measures ANOVA was used for within-group comparisons. Pairwise comparisons were analyzed using independent T-test.

Results

Thirty-one children participated in the study, and 10 students (seven male, three female) who met the inclusion criteria completed the whole study. The subjects acted as their controls at baseline and followed without intervention for 6 months, and later were reassessed before and after a short-term SM intervention for a period of 5 weeks. The features of the sample

are reported in Table 1. Within subjects factors for Manuscript-MHA and D'Nealian-MHA are reported in tables 2 and 3. Post intervention changes in MHA score for Manuscript & D'Nealian style are reported in table 4. Paired-sample t-test (HPSQ) and Grip strength are reported in table 5.

Discussion

This study addressed the need for further research on handwriting remediation and we investigated the effectiveness of short-term SM intervention on handwriting performance in elementary school children. The first hypothesis was that children receiving intervention would show substantial improvement in handwriting performance. The short-term training had beneficial effects on MHA scores of rate, legibility, form, alignment, size and spacing in both the manuscript and D'Nealian scripts. The teacher perception of student handwriting assessed on HPSQ showed a significant difference in all the domains, that is, legibility, performance time, physical and emotional components after the intervention. Handgrip strength improved after the intervention, as recorded with Jamar hand-held dynamometer.

The students were followed longitudinally from grade 1 without any intervention until grade 2, thereafter the short-term SM intervention program was carried out for 5 weeks, twice per week. The short intervention produced a remarkable improvement in handwriting MHA scores, except for rate in manuscript style, but showed improvement in D'Nealian script. The rate scores were not significantly improved, which was supported by other studies, given that rate is not associated with function. Studies examining the correlation between handwriting speed and legibility have yielded contradictory findings.³⁷ Given that students are instructed to write as neatly as possible, the speed of handwriting is decreased despite the intervention. The improvement in D'Nealian script rate score may be attributed to the curriculum of the school. The other variables of MHA, such as legibility, form, alignment, size and spacing reached statistical significance ($P < 0.05$). The strong individual scores for improvement in these variables is attributed to the SM intervention. The program has components similar to the handwriting and writing interventions developed by Denton *et al.* emphasizing critical elements of SM intervention.^{29,32} Ninety percent of Canadian OT and 92% of US school-based OT surveyed used SM approaches to remediate handwriting.^{31,33} Earlier studies have been conducted to explore potential factors that may contribute to handwriting difficulties. The intrinsic factors include kinesthesia, fine motor skills, eye-hand coordination, visual perceptual skills, and visual motor integration, and extrinsic factors include writing posture, chair, and desk height; these are believed to have a relationship with handwriting.² In this study, emphasis was therefore placed on both intrinsic and extrinsic factors to improve handwriting skills.

In the SM approach, interventions are oriented to the child's sensory systems, and provide a variety of sensory experiences with appropriate feedback to improve motor

performance. Apart from the SM approach, additional factors such as paper position, writing surface, grip strength, and posture were also considered. Therapists acted in close collaboration with teachers to eliminate these extrinsic factors and thereafter focus on motor planning abilities. Case-Smith *et al.* developed an integrated handwriting program that produced large, significant gains in handwriting legibility and speed, which were maintained at 6 month follow up.^{28,34} Mackay *et al.* found that the Log Handwriting Program improved children's writing legibility. Legibility improved by a mean of 4.1 points (95%CI: 2.5–5.7); form, 5.3 points; alignment, 7.8 points; size, 7.9 points; and space, 5.3 points. Speed decreased by 3.9 points.³³ The present results agree with these aforementioned studies, emphasizing the importance of SM-based intervention taking into account the extrinsic factors. Other SM-based programs have resulted in little or no effect on handwriting performance when compared with traditional handwriting instruction.^{29,30,37}

Limitations

Pupils in this study were chosen via convenience sample from the British International School in Riyadh. The initial plan was to recruit students for control and experimental groups, but this could not be done due to low recruitment numbers. The sample size was small and limited to parents who agreed to have their child involved in the study. Whether a single intervention or a combination of intervention strategies was the cause of improvement is not known. This could have biased the sample, because there was no control group in the study. Students in this study were homogeneous, having a similar preschool experience.

Future research

The authors recommend that the subjective and objective standards of handwriting analysis must be implemented in schools to analyze handwriting difficulties. Thus, sensitive and evidence-based strategies, rather than intuition-based strategies, need to be used to right the problems in hand. While teachers are skilled at informally identifying poor handwriting, the MHT and HPSQ help to support the teacher's subjective judgement of poor-quality writing. This evidence-based approach helps to document the problem and plan adequate measures to counter the problem in the early phases.

The role of handwriting efficiency in the writing of young children has been underestimated in mainstream education and appropriate SM interventions are helpful. SM intervention is an evidence-based protocol that can be recommended by practitioners for effective printing instruction in the classroom or institutional level.

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Disclosure

The authors declare no conflicts of interest.

Author contributions

A.A.A. and G.R.M. designed the study; G.R.M. and S.B. collected data; A.A.A. and S.B. analyzed the data; A.A.A., G.R.M., and S.B. wrote the manuscript. All authors read and approved the final manuscript.

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Supporting Information

Additional Supporting Information may be found in the online version of this article at the publisher's web-site:

Appendix S1 Sensorimotor activities for elementary school children.