Testing the Effect of Kinesthetic Training on Handwriting Performance in First-Grade Students

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OBJECTIVE. The purpose of this study was to investigate the effect of kinesthetic training on handwriting performance in first-grade students 6 to 7 years of age who had kinesthetic deficits and handwriting difficulties.

METHOD. With a randomized–blinded three group research design, 45 children were assigned to either a kinesthetic training group, a handwriting practice group, or a no treatment group. Kinesthesia and handwriting legibility were measured before and after intervention. Teachers’ judgments of handwriting legibility in the classroom setting were sought at 4 weeks after the intervention to see whether any improvement gained would be maintained in the natural setting. Two-way repeated-measures analysis of variance was used for data analyses.

RESULTS. At posttest, all groups showed significant improvement of kinesthesia, with no significant difference in the magnitude of improvement among the groups. There was no significant improvement of handwriting legibility as measured by a standardized test in any of the groups, although teachers indicated improvement of handwriting legibility in the classroom setting in all groups. Teachers also reported maintenance of handwriting legibility at 4 weeks after posttest.

CONCLUSION. Kinesthetic training did not improve handwriting or kinesthesia in these children. The findings of this study offer no support for use of kinesthetic training to improve handwriting legibility in first-grade students.


Learning to write is one of the major occupations of childhood (Amundson, 1992; McHale & Cermak, 1992). Children’s handwriting performance is of concern to occupational therapists, educators, and parents because it is an essential skill required to participate in educational activities successfully. Difficulties with handwriting can be resistive to change even after several years of formal handwriting education (Alston & Taylor, 1987; Rubin & Henderson, 1982).

Kinesthesia is a sense of movement and position of the limbs that arises from information from the muscles, joints, and skin (McClosky, 1978). On the basis of their closed-loop theory of motor control, Laszlo and Bairstow (1984) proposed that kinesthetic feedback is essential to handwriting development. They proposed that kinesthetic information has two functions in the performance and acquisition of handwriting: It provides ongoing error information, and it is stored in memory to be recalled when the writing is repeated. Error information leads to error correction programming, and the upgraded program generates its own kinesthetic input when executed. Storage of this input leads to improved programming in subsequent attempts at handwriting and is responsible for improvement in handwriting skill. Therefore, if kinesthetic information cannot be perceived or used, efficient programming cannot occur. A child with kinesthetic impairment will find writing difficult and will be unable to improve his or her writing performance through practice because lack of kinesthetic error detection and error correction
lead to inability to improve motor programs necessary for writing (Laszlo & Bairstow, 1984).

Laszlo and Bairstow (1983, 1985b) proposed a kinesthetic intervention with the underlying assumptions that kinesthesia can be changed through training and that improvement in kinesthesia will lead to improvement in motor performance, including writing. This kinesthetic training program consists of intensive daily training of 2 weeks or less to improve motor performance by improving two aspects of kinesthesia: kinesthetic acuity, or the ability to discriminate between relative positions and movements of two upper limbs, and kinesthetic perception and memory, or the ability to perceive and recall movement patterns of an upper limb.

The effectiveness of this kinesthetic training program to improve handwriting in children has been investigated in a few studies with varied results. In a study of 30 school children 5 to 7 years of age, Harris and Livesey (1992) found that the children who received kinesthetic training showed significantly greater improvement in handwriting than the children who received handwriting practice. Escribano (1991) further investigated the relationship between the kinesthetic training program and handwriting performance in 23 children 7 to 8 years of age and found no significant handwriting improvement in either the kinesthetic training group or the no treatment group. Sims, Henderson, Hulme, and Morton (1996) studied 20 children 8 to 9 years of age who were clumsy and found no significant improvement of handwriting immediately after treatment in either the kinesthetic training group or the no treatment group. However, the children in both groups showed improvement at follow-up approximately 3 months after the treatment. In a second study of 36 children 6 to 10 years of age who were clumsy, these researchers found that both the kinesthetic training group and the alternative treatment group (activities not related to kinesthetic training) did not show significant improvement in handwriting at either posttest or 4-month follow-up as judged by blind-rated raters (Sims, Henderson, Morton, & Hulme, 1996). Only the Parents/Teachers Checklist, a measure of parents’ and teachers’ judgment, showed improved handwriting at follow-up for both study groups.

Based on the studies reviewed, the effect of kinesthetic intervention on handwriting performance has not been clearly established. One of the reasons for lack of agreement could be several methodological issues found in those studies. The present study was intended to address these methodological problems, including small sample size, lack of screening of either kinesthetic impairment or handwriting difficulties before training, use of only subjective judgment of handwriting, lack of control for experimenter bias in test administration and scoring, and omission of standardized procedures for kinesthetic testing. This study also investigated the effect of kinesthetic training on handwriting speed because speed is an important aspect of handwriting performance (Alston & Taylor, 1987; Amundson, 1995; Mojet, 1991). Levine (1987) proposed that kinesthetic impairment in children might lead to decreased speed of handwriting because of either the excessive pressure needed for kinesthetic feedback or the slower visual feedback used to substitute for kinesthetic feedback.

The purpose of this study, therefore, was to investigate whether kinesthetic training would lead to improvement in kinesthesia and handwriting performance in first-grade students. Handwriting performance included both handwriting legibility and handwriting speed. The hypothesis was that children who received kinesthetic training would show significantly more improvement in both kinesthesia and handwriting performance than children who received either handwriting practice or no treatment.

**Method**

**Design**

This study used a randomized–blinded three group research design. The three groups were a kinesthetic training group, a handwriting practice group, and a no treatment group. Each child was tested on three occasions: pretest within 1 week before treatment, posttest within 1 week after treatment, and follow-up at 4 weeks after posttest. Both the evaluators and the teachers were blinded to the treatment conditions. In addition, the children were not aware of the study hypothesis.

**Instruments**

Kinesthetic Sensitivity Test (KST). Laszlo and Bairstow (1985a) developed the KST to measure kinesthetic sensitivity while eliminating the confounding factor of motor control on test performance by using passive movements during testing. The KST provides normative data for 5-year-old to 12-year-old children and for adults. The KST contains two subtests, the Kinesthetic Acuity subtest (Runway task; see Figure 1) and the Kinesthetic Perception and Memory subtest (Pattern task; see Figure 2). The test–retest reliability coefficients of the Runway task were reported to be .69 for 6-year-olds and .52 for 7-year-olds, whereas that of the Pattern task were .38 for 6-year-olds and .16 for 7-year-olds. To combine the scores of both subtests to obtain a valid overall score of kinesthesia, each raw score

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1 This study was conducted after Harris and Livesey’s (1992) study. The date discrepancy was due to publication delay.
was transformed into a $Z$ score based on the norm for each age group provided by the test manual.

Kinesthetic Acuity subtest (Runway task). The Runway task equipment consists of two table-top runways that can be adjusted independently from $0^\circ$ to $22^\circ$ from the horizontal. Each child was required to discriminate the relative heights of the two runways set at different degree angles while vision was obstructed with a masking box. The child’s hands (each holding onto a peg at the base of each runway) were passively moved simultaneously up and down the runways, and the child was asked to indicate which hand went up higher. The degree differences were presented according to the standardized testing procedures. The score of the Runway task for each child is the number of correct responses from 32 trials.

Kinesthetic Perception and Memory subtest (Pattern task). For the Pattern task, a stylus, which the child held with the hand normally used for writing, was passively guided to trace each of four stencil patterns while the child’s vision was obstructed with a masking box. The experimenter then rotated the pattern from its original position. The masking box was removed, and the child was asked to reorient the pattern to its original position with the aid of vision. The score of the Pattern task is the average degree angle of the absolute errors (deviation from the correct orientation) from four trials.

Evaluation Tool of Children’s Handwriting (ETCH). Designed for use with 6-year-olds to 12-year-olds, the ETCH (Amundson, 1995) is composed of assessments for two types of handwriting: manuscript and cursive. Only the assessment for manuscript was used in this study. This test measures both handwriting legibility and handwriting speed using six evaluation tasks that resemble tasks required during classroom participation: writing the alphabet from memory, writing numbers from memory, copying from a near-point model, copying from a far-point model, writing from dictation, and composing a sentence. Three total legibility scores—total letter legibility, total word legibility, and total numeral legibility—were calculated for each child. Each total legibility score came from the number of legible letters, words, and numbers from all tasks combined and then transformed into percentages based on the possible letters, words, and numbers, respectively. A higher percentage represented a higher level of legibility. For speed, a stopwatch was used to time the children during the copying tasks and composition task.

The test–retest reliability coefficients of this test for first-grade and second-grade students are .63 for total numeral legibility, .77 for total letter legibility, and .71 for total word legibility (Diekema, Deitz, & Amundson, 1998). The test administration time for the ETCH was approximately 15 min to 20 min per child.

Teacher questionnaire. This tool was developed for this study. The questionnaire was used to obtain teachers’ judgments of the children’s handwriting legibility during classroom activities compared with other children in the same class. Teachers were asked to indicate whether the child’s overall handwriting legibility in the classroom setting was much below average, below average, slightly below average, average, slightly above average, above average, or much above average. A score was assigned to each choice, ranging from –3 for much below average to 3 for much above average.

Participants

A power analysis (Cohen, 1988) with a desired power of .80 at a significance level of .05 using an estimated effect size ($r$) of .43 indicated a required number of 15 children per group. Therefore, 45 first-grade students were recruited for this study. First-grade students were selected because children in first grade had demonstrated greater improvement in handwriting than children in kindergarten who had less experience with formal handwriting in a previous study (Harris & Livesey, 1992). The estimated effect size was obtained from Harris and Livesey’s (1992) study, which had the greatest internal validity of the studies reviewed.
Each child met the following inclusion criteria: (a) kinesthetic deficit as determined by KST scores at or below the 25th percentile in one or both subtests, (b) handwriting difficulties during classroom activities as indicated by the classroom teacher, (c) normal or corrected vision and hearing as indicated by the classroom teacher, (d) full passive range of motion and normal muscle tone of both arms as determined by the first author or research assistants, and (e) appropriate attention span within the classroom setting as observed and indicated by the classroom teacher. Because studies have indicated no gender difference in kinesthesia (Bairstow & Laszlo, 1981; Laszlo & Bairstow, 1985b; Livesey & Intili, 1996), an equal number of boys and girls was not sought. Studies also have found that right-handed and left-handed children were not significantly different in their kinesthetic abilities (Bairstow & Laszlo, 1981; Laszlo & Bairstow, 1985b); therefore, both left-handed and right-handed children were included. The only exclusion criterion was that a child could not be on medication to improve attention span.

The children were recruited from 24 elementary schools within 2 school districts in the greater Boston area. Thirty boys and 15 girls whose parents consented to participate were included. Their ages ranged from 6 years 2 months to 7 years 11 months (M = 6 years 11 months, SD = 5 months). One child was dismissed during the study because of extensive school absences, and another child recruited for replacement.

Treatment Protocols

Kinesthetic training group. The two training tasks were presented in a counterbalanced order over a 6-day training period. The number of six training sessions was justified by the findings from Harris and Livesey’s (1992) study in which children showed improvement in handwriting after six training sessions of the same kinesthetic intervention as this study. Each training session lasted 30 min. A small sticker was given at the end of each training session to help maintain the children’s interest in the training tasks.

In each session of the runway task training, the child was asked to differentiate with vision occluded the height of his or her arms on two table-top runways. The runways were the same as those used for kinesthetic acuity testing, but the differences between the runways were different. The first difference in angle between the runways was set at 20°. The difference was reduced to 16°, 12°, 8°, and 4° in succeeding trials. Children progressed to the next step only if they gave the correct answer for four out of five trials at each difference in angle. The positions of the hands (which hand was to be higher) were randomly assigned for the training trials. Verbal feedback of whether the child gave the correct answer for each trial was provided. Visual feedback was also provided if the child gave two consecutive incorrect answers by allowing the child to see his or her hand position. Encouragement and positive reinforcement were provided throughout the sessions. Training time for this task was 15 min per session.

In each session of the pattern task training, the child was asked to reorient one of six stencil patterns presented in order of the least to the most complex. The patterns were different from those used for kinesthetic perception and memory testing. The child held a stylus, which was guided by the trainer through the cutout on a stencil pattern while the child’s vision was blocked. The trainer then rotated the pattern and asked the child to look at the pattern and rotate it back to its original position. The child moved to the next, more difficult stencil only after he or she made no more than a 15° error for a particular pattern. The degrees of original positions, direction of rotation (clockwise, counterclockwise), and rotation degrees were randomly presented during the training session. Visual feedback was given by showing the correct original position after the child finished reorienting the pattern for each trial. Training time for this task was 15 min per session.

Handwriting practice group. For each child, six training sessions comparable in time and attention to the kinesthetic training group were conducted. The child was given letters, words, and sentences to copy. The handwriting tasks were presented from the least to the most complex (letters, shorter words, longer words, shorter sentences, longer sentences, paragraphs) to ensure the same features as the approach used in the kinesthetic training tasks. The handwriting practice books used one of the three different alphabet systems—Zaner-Bloser, palmer, and D’Nealian—to maintain ecological validity of the practice in relation to the children’s actual handwriting in the classroom. Verbal and visual feedback were provided for letter size, alignment, and spacing. The training time for this task was 30 min. A small sticker was provided at the end of each training session to help maintain the children’s interest in the training tasks.

No treatment group. The children in this group continued to participate in their usual academic activities in the classroom. They were pulled out of the classroom only for pretesting and posttesting on a timeline similar to the children in the other groups.

Procedure

The children were randomly assigned to one of the three groups in blocks of three on the basis of order of entrance into the study. Treatments began within 1 week after pretest on the KST, the ETCH, and the teacher questionnaire. Kinesthetic training or handwriting practice was provided 30 min daily for 6 consecutive school days. In the cases
Effect of Kinesthetic Training on Handwriting Legibility

Objective measurement (ETCH). ETCH scores for total word legibility, total letter legibility, and total numeral legibility were analyzed separately. These scores were not combined because they overlap. That is, the total letter and numeral scores are smaller unit scores that contribute to the level of total word scores (although not 100%). Therefore, the scores were highly correlated and not considered appropriate to combine or average to obtain a “total” score.

For the ETCH total word legibility scores, no signifi-

ence was found among the groups for either the Runway task or the Pattern task. Therefore, the groups were accept-
ably comparable at the beginning of the study (see Table 1).

Effect of Kinesthetic Training on Kinesthesia

The KST score, which is a sum of the Runway and Pattern task Z scores and represents a general level of kinesthetic sen-
sitivity of each child, was used for analysis. In addition, the Runway and Pattern task scores were analyzed separately to examine the pattern of change for each aspect of kinesthesia after kinesthetic training. Only 44 observations were available for the analyses because of one missing set of data of the posttest KST scores in the handwriting practice group.

Significant improvement of KST scores occurred over time, $F(1, 41) = 12.24, p = .001$; however, this improvement was not significantly different among the groups, $F(2, 41) = .78, p = .47$. When the Runway and Pattern task scores were analyzed separately, no significant improvement occurred in Runway task over time, $F(1, 41) = 2.06, p = .16$. The group × time interaction also was not significant, $F(2, 41) = .14, p = .87$. For Pattern task scores, a significant improvement of Pattern task from pretest to posttest was found, $F(1, 41) = 8.06, p = .007$, although the improvement in Pattern task scores was not significantly different among the three groups, $F(2, 41) = .60, p = .55$.

Results

Group Compatibility at Pretest

Using one-way ANOVA, no significant differences at pretest among the three groups for KST, ETCH total word legibility, ETCH total letter legibility, ETCH total numeral legibility, or level of handwriting legibility as judged by their teachers were found. Additionally, when each component of KST scores was examined separately, no significant differ-

ence was found among the groups for either the Runway task or the Pattern task. Therefore, the groups were accept-
ably comparable at the beginning of the study (see Table 1).

Effect of Kinesthetic Training on Handwriting Legibility

Objective measurement (ETCH). ETCH scores for total word legibility, total letter legibility, and total numeral legibility were analyzed separately. These scores were not combined because they overlap. That is, the total letter and numeral scores are smaller unit scores that contribute to the level of total word scores (although not 100%). Therefore, the scores were highly correlated and not considered appropriate to combine or average to obtain a “total” score.

For the ETCH total word legibility scores, no signifi-
cant difference was found between pretest and posttest, $F(1, 42) = .003, p = .96$. The group x time interaction also was not significant, $F(2, 42) = .63, p = .54$.

For the ETCH total letter legibility scores, no significant change occurred over time, $F(1, 42) = .63, p = .43$, and changes from pretest to posttest were not significantly different among the groups, $F(2, 42) = .66, p = .52$.

For the ETCH total numeral legibility scores, no significant difference was found from pretest to posttest, $F(1, 42) = 1.30, p = .26$. The group x time interaction also was not significant, $F(2, 42) = 1.36, p = .27$.

Because it is arguable that the lack of improvement in the total ETCH scores could be influenced by other factors, such as ability to recall (as in alphabet and numeral writing tasks), auditory processing (dictation), and spelling (sentence composition), the near-point copying and far-point copying tasks of the ETCH, which did not require these abilities, were further examined separately. No significant change was found from pretest to posttest of any score category in any of the groups: near-point word legibility, $F(1, 42) = .72, p = .40$; near-point letter legibility, $F(1, 42) = .00, p = .99$; far-point word legibility, $F(1, 42) = .64, p = .43$; and far-point letter legibility, $F(1, 42) = .04, p = .84$. The group x time interactions were not significant: near-point word legibility, $F(2, 42) = .02, p = .98$; near-point letter legibility, $F(2, 42) = 1.48, p = .24$; far-point word legibility, $F(2, 42) = 1.03, p = .37$; and far-point letter legibility, $F(2, 42) = .08, p = .92$.

**Subjective measurement (teacher questionnaire).** Significant improvement of teacher questionnaire scores was found from pretest to posttest, $F(1, 42) = 52.12, p = .0001$. However, the amount of improvement was not significantly different among the groups, $F(2, 42) = .19, p = .83$. When the teacher questionnaire scores from posttest to follow-up were examined, a significant improvement was found, $F(1, 42) = 4.14, p = .048$. The improvement was, however, not significantly different among the three groups, $F(2, 42) = 1.07, p = .35$.

**Effect of kinesthetic training on handwriting speed.** The combined writing time for near-point copying and far-point copying tasks was used to represent handwriting speed because of the relatively few intervening factors that could affect the writing time. This time represented typical writing time because children were instructed to write at their usual pace during ETCH testing. No significant change in writing time was found from pretest to posttest, $F(1, 42) = 2.5, p = .12$. The group x time interaction also was not significant, $F(2, 42) = 1.22, p = .31$.

**Discussion**

Significant improvements of kinesthesis and handwriting legibility were found as judged by the teachers in all groups, whereas no significant improvement of handwriting legibility was found as measured by the standardized measurement tool or handwriting speed in any of the groups. These findings are different from those of past studies. The hypothesis that children who received kinesthetic training would improve significantly more in both kinesthesis and handwriting performance than children who received either handwriting practice or no treatment was not supported. Kinesthetic training was not any more effective than either handwriting practice or no treatment. The outcome of this study puts the theory proposed by Laszlo and Bairstow (1985b), on which the intervention is based, into question.

Three possible explanations need to be examined when attempting to interpret this outcome. First, kinesthetic and handwriting improvement (as judged by teachers) are related. Second, kinesthetic and handwriting improvement (as judged by teachers) have no direct relationship to each other. Third, the improvements seen may not represent a valid change of skills but rather a result of some uncontrolled measurement artifacts.

**Improvement in Kinesthesis and Handwriting Are Related**

Under this interpretation, the most likely explanation for kinesthetic improvement in all three groups is the exposure to the KST at pretest. Possibly being exposed to the KST had made the children more aware of their own movements. Consequently, their kinesthetic ability improved and led to improvement in their judged handwriting ability. This speculation, however, cannot be confirmed because of the lack of a non-pretest control group in the present study and lack of sufficient evidence from past research. A future study using the Solomon design (Campbell & Stanley, 1963) to control the exposure to pretest will help to answer the question of the influence of pretest exposure.

Subsequently, an explanation is needed about why teachers indicated improvement but the ETCH did not. Upon examination of the ETCH scoring criteria, certain aspects of handwriting, such as the ability to write on line, letter size, alignment, and the consistency of letter size and alignment within a sentence, would not be reflected by the ETCH scores, which reflect only global legibility (i.e., overall readability of letters, words, and numbers regardless of their appearances). It is conceivable that if the children showed improvements in those aspects, their written work would have looked tidier and neater in the teachers’ eyes, although those improvements would not have earned higher scores on the ETCH unless they changed the readability level of letters, words, and sentences. For future intervention studies, another tool that captures the other handwriting features as described should be considered in addition to measurement of global legibility.
Improvement in Kinesthesia and Handwriting Are Not Related

In the case that improvement in kinesthesia is not related to improvement in handwriting, natural development is the most likely explanation for the outcome. At the time of this study (which was later in the school year), the children had already received a substantial amount of handwriting education. Therefore, this period may already be a crucial one where gain would be expected even without additional interventions. Nonetheless, it seems extraordinary that the majority of the children would make significant gain of both kinesthesia and handwriting within a period of approximately 10 days. The explanation for the discrepancy between the improvement indicated by teachers and the ETCH score mentioned earlier also applies here.

Existing longitudinal developmental studies of handwriting have only examined the developmental pattern of cursive handwriting of children in second grade and up (Blöte & Hamstra-Blerz, 1991; Hamstra-Blerz & Blöte, 1993; Smits-Engelsman & Van Galen, 1997) and over a long interval of at least 1 year. The lack of evidence for developmental progression of kinesthesia also makes it impossible to confirm the speculation for natural development of kinesthesia. For future research, multiple baseline measurements of these two variables before treatment will help to identify children’s developmental patterns, which can be compared with the pattern during the training period.

Improvements in KST and Teacher Questionnaire Scores Are Due to Artifacts

When extreme scores are used, a tendency exists for the phenomenon of regression toward the mean even if no real change occurs (Campbell & Stanley, 1963), especially for a measurement instrument with low test–retest reliability, such as the KST. In the present study, the pretest scores of all children were on the extreme low end (at or below the 25th percentile); therefore, the scores at posttest, according to Campbell and Stanley (1963), were likely to be higher even if no real improvement occurred. In support of this explanation, the significant improvement in KST scores was mainly the result of the improvement in Pattern task scores, which have very low test–retest reliability (.38 for 6-year-olds, .16 for 7-year olds), whereas the Runway task scores, which have higher test–retest reliability (.69 for 6-year-olds, .52 for 7-year-olds) did not show significant improvement.

To minimize the effect of regression toward the mean in future studies, a more reliable tool is needed for kinesthesia measurement. Changes may be needed in the testing procedure or the equipment structure. It has been shown that young children are capable of producing consistent responses (test–retest reliability of $r = .896$) when a different test of kinesthesia is used (Livesey & Coleman, 1997). Therefore, an acceptable test–retest reliability of a test designed to measure kinesthesia is possible to achieve and is needed for a more reliable score. Although it has an acceptable test–retest reliability, the test developed by Livesey and Coleman (1997) was not appropriate for measuring the outcome of the kinesthetic intervention used in the present study because no evidence exists that it measures the same aspects of kinesthesia as those targeted by the Laszlo and Bairstow kinesthetic intervention.

Another possibility is that the KST scores increased because of practice effect. This increase does not represent the improvement in kinesthesia but, rather, represents improvement in test-taking skills because of repeated test taking. The finding that the KST scores increased in all groups, with the largest increase seen in the kinesthetic training group, seems to support this explanation. It is logical that children in the kinesthetic training group would be expected to show the largest increase of the KST scores because they had the most practice. Again, taking multiple baselines before the treatment period as well as using a no-pretest control group in a future study would help to clarify the practice effect issue.

The increase in teacher questionnaire scores could have been a result of the teachers’ expectations. No teachers were aware of group assignments, as they indicated in the posttest questionnaire, even for children who were in the no treatment group. The children who received no treatment were taken out of the classroom four times for testing (the teachers were not aware of that purpose), and the teachers could have thought that those children received some type of treatment during those times. The teachers’ thought that all children received treatment may provide an alternative explanation from what was stated earlier about why the teacher questionnaire, which is a subjective judgment, showed improvement in handwriting whereas the ETCH, which is an objective measurement, did not.

Limitations

The first limitation of this study is that the kinesthetic intervention proposed by Laszlo and Bairstow (1983) may not represent kinesthetic intervention presently used by occupational therapy practitioners in the United States. However, interpretation of these results can be the first step to questioning and examining theories that support the use of kinesthesia in treatment regimes that assume a direct relationship exists between kinesthesia and motor performance in children.

The second limitation is that the results can only be generalized to children who have similar characteristics to those who participated in this study. The effect of kines-
thetic training on handwriting performance may be different in other groups of children.

Conclusion

The prediction that improvement in kinesthesia after kinesthetic training would lead to improvement in motor performance on the basis of the feedback control theory was not upheld. Effectiveness of the kinesthetic intervention on handwriting performance was not demonstrated in this study. Based on these results, not enough evidence supports the use of this intervention in clinics or school settings for the purpose of handwriting remediation at this time, at least for children with similar characteristics to those who participated in this study. ▲

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References