



Original Article

The correlation between proprioception and handwriting legibility in children

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Abstract. [Purpose] This study investigated the association between proprioception, including joint position sense and kinetic sense, and handwriting legibility in healthy children. [Subjects and Methods] Assessment of joint position sense, kinetic sense, and handwriting legibility was conducted for 19 healthy children. Joint position sense was assessed by asking the children to flex their right elbow between 30° to 110° while blindfolded. The range of elbow movement was analyzed with Compact Measuring System 10 for 3D motion Analysis. Kinetic sense was assessed using the Sensory Integration and Praxis Test. The children were directed to write 30 words from the Korean alphabet, and the legibility of their handwriting was scored for form, alignment, space, size, and shape. To analyze the data, descriptive statistics and Spearman correlation analysis were conducted using IBM SPSS Statistics 20.0. [Results] There was significant negative correlation between handwriting legibility and Kinetic sense. A significant correlation between handwriting legibility and Joint position sense was not found. [Conclusion] This study showed that a higher Kinetic sense was associated with better legibility of handwriting. Further work is needed to determine the association of handwriting legibility and speed with Joint position sense of the elbow, wrist, and fingers.

Key words: Handwriting, Joint position sense, Kinesthesia

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INTRODUCTION

Handwriting is an essential fine motor skill in school-aged children¹⁾. Children spend from 31 to 60% of their school day either writing or performing other fine motor tasks²⁾. Handwriting legibility affects readability. The preparatory skills for writing are coordination of multiple joints, visual perception, vision-motor integration, and proprioception³⁾.

Proprioception relays information on body position from muscles and joints to the brain⁴⁾. Together with stereognosis, proprioception allows smooth joint movement when vision is impaired or absent⁵⁾. Children with poor proprioception have problems with handwriting legibility because their grip on a pen is too strong or too weak⁴⁾. Generally, proprioception can be measured with joint position sense (JPS) and kinesthetic sense (KS)⁶⁾. While there are many studies investigating children's handwriting, quantitative studies on the association between handwriting and proprioception involving JPS and KS are lacking⁷⁾.

The aim of this study was to investigate the association between proprioception, involving JPS and KS, and handwriting legibility in children.

SUBJECTS AND METHODS

Nineteen healthy children (15 boys and 4 girls) with an average age of 9.7 ± 0.36 years participated in this study. All subjects were right-handed. Children with musculoskeletal diseases were excluded. Prior to the study, the children and

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their parents were informed about the purpose of the study and the general procedures to be undertaken. All children and parents signed an informed consent form. The study was approved by the Kaya University of Human Health Science Studies Committee.

Proprioception was measured in terms of JPS and KS. JPS was measured with the children blindfolded and sitting on a chair. The investigator moved the child's right arm passively through 80° of flexion at the elbow (from 30° to 110°). The children were then directed to repeat this motion 10 times following a metronome set at 1 s intervals. Their movements were recorded by a Compact Measuring System (CMS) 10 for 3D Motion Analysis (Using the Winarm software Zebris Medical GmbH, Germany). CMS markers were placed at the greater tubercle and lateral epicondyle of the right humerus and at the right wrist. Angles of deviation from the targeted range of flexion were analyzed using Matlab version 2014a (The Math Works Inc., 2014).

KS was measured by the kinesthesia item in the Sensory Integration and Praxis Tests (SIPT, WPS, Torrance, CA, USA). The test sheet comprises 11 lines of differing directions and distances. The investigator moved a finger of the subject passively along a line from beginning to end, allowing the child to learn the line direction and distance. Then, blindfolded and after one trial, the children were directed to trace five lines for each hand. Only the results of the right hand were analyzed in this study. The investigator then measured the distance between the test endpoints and the real endpoints of the lines. The distance is inversely proportional to accuracy of KS.

The Korean alphabet was used to assess the legibility of handwriting. Two elementary school teachers selected thirty test words from a Korean textbook. Legibility was evaluated using form, alignment, space, size, and slope⁸⁾.

High scores equate to high legibility. The legibility score was calculated as the ratio of the number of clearly written words to the total number of words (Score for legibility (%) = Number of letters that received 5 points/30 × 100). Higher scores mean better legibility. All data were analyzed using IBM SPSS Statistics 20.0 (IBM Corp., Armonk, NY, USA). Spearman's rank correlation was used to determine the relationships between legibility of handwriting and JPS and KS, with significance defined as $p < 0.05$.

RESULTS

Values obtained for JPS and KS in relation to handwriting legibility are shown in Table 1. There was no correlation between writing legibility and JPS at either 30° or 110° of elbow flexion ($p > 0.05$). A high KS correlated significantly with legible handwriting ($p < 0.05$, Table 2).

DISCUSSION

This study investigated the association between the legibility of handwriting and JPS and KS in young children. Children aged between 7 and 8 years are expected to be proficient in building up their speed of handwriting, ensuring consistency in size and proportions of letters as well as the spacing between letters and words⁹⁾. The average age of the participants in this study was 9.7 years old.

Some authors question the reliability of tests for JPS¹⁰⁻¹²⁾. The SIPT has been shown to be reliable¹³⁾. Our results showed that a highly accurate KS was associated with higher legibility scores. Laszlo and Bairstow¹⁴⁾ proposed that kinesthetic feedback has two functions in handwriting. KS provides ongoing error information and memory storage to be recalled when writing is repeated. A high KS leads to programmed error correction, and the upgraded program generates better writing legibility. The results of this study support the hypothesis that KS reinforces the linkage between visual and motor control required for clear handwriting¹⁵⁾.

We found no correlation between handwriting legibility and JPS at the elbow joint. We studied JPS at the elbow joint because proprioception at the elbow joint is necessary for performing fine manipulative tasks including handwriting¹⁶⁾. However, clear handwriting requires coordinated movement involving multiple joints. Studies have reported that proprioception at the wrist joint¹⁷⁾ and finger joints¹⁸⁾ influences handwriting legibility. Future studies need to analyze JPS of fingers and the wrist.

Table 1. Handwriting legibility and proprioception test results (N=19)

	Mean ± SD*
Joint position sense 110° (degree)	22.530 ± 10.063
Joint position sense 30° (degree)	14.256 ± 10.408
Kinesthetic sense (cm)	2.044 ± 0.703
Handwriting legibility (%)	33.521 ± 15.852

*Standard deviation

Table 2. Correlation between handwriting legibility and proprioception (N=19)

	Handwriting legibility (%)
Joint position sense 110° (degree)	0.016
Joint position sense 30° (degree)	-0.009
Kinesthetic sense (cm)	-0.370*

* $p < 0.05$

This study has some limitations. The small sample size is insufficient to represent the population. We looked at children within a limited age range—between 9 and 10 years of age. Further, we did not control for other factors that affect writing legibility, such as fine motor control and visual-motor integration^{19–21}). Finally, although handwriting quality is measured in terms of legibility and speed, this study investigated only writing legibility.

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