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Dexterity and two-point discrimination of the hand in school-aged children with dysgraphia

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Abstract

Background: Dysgraphia as a problem with handwriting, affects student's performance in school activities and participation. The purpose of the study was to compare dexterity and two-point discrimination of the hand between learning disabled students with dysgraphia and healthy students.

Methods: Forty-three students with developmental dysgraphia and 55 normal students in grade two to four from special and regular schools participated in this study. Hand dexterity and static/dynamic discriminative touch were assessed via Purdue Pegboard and Two-Point Discriminator respectively.

Results: Significant differences were found in Purdue Pegboard scores between two groups except in doing the test with the left hand ($p<0.05$). Purdue Pegboard scores were significantly lower in left-handed children with dysgraphia compared to healthy children ($p<0.05$). There was no significant difference in dynamic two point discrimination between two groups of children ($p>0.05$). Static two-point discrimination of the thumb finger was significantly higher in children with dysgraphia ($p<0.05$).

Conclusion: Hand dexterity affects handwriting performance in children with dysgraphia. There were no correlations between two-point discrimination and Purdue Pegboard scores of children with dysgraphia. Intervention should focus on other aspects of dexterity rather than sensory components. Hand dominancy also may be a factor influencing hand performance in dysgraphia.

Keywords: Learning disability, dysgraphia, hand, dexterity, two point discrimination.

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Introduction

Handwriting is the visible form of spoken language (1) and according to the International Classification of Functioning, Disability and Health (child and youth edition), it is an essential occupation for learning and application of knowledge (2). Handwriting is a complex perceptual motor skill which consisting a blend of visual motor coordination abilities, motor planning, perceptual and cognitive skills as well as tactile and kinesthetic sensitivities (3,4). Despite recent progress in information technology, handwriting is a necessary skill for education, social communication, and other areas of daily life yet (5). Primary school students spend approximately half time of the school day to accomplish handwriting tasks or writing assignment (4). Developmental dysgraphia can be characterized as the disorder of written expression difficulties that writing skills are substantially below those expected given the person's chronological age, measured intelligence, and age-appropriate education (6). Handwriting and fine motor problems are the most common reasons for referral to professional help, especially school-based occupational therapy in these children (7). Ten to thirty percent of normal school-aged children and 90 to 98 percent of children owing developmental and learning disabili-

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ties are reported to experience difficulties in handwriting proficiency (5,8). Various factors influence on legibility and speed of handwriting such as visual perception, cognition, visual motor coordination, and fine motor control (3,9-11). Dexterity as a complex fine motor skill of the hand is an outcome of sensory information processing in multiple layers of the nervous system provided by various sensory subsystems (12). Positive correlation between the motor function of the hand and hand sensation in the normal population is evident (3,13). More studies have examined the perceptual components of handwriting in learning disabled children, and they did not pay attention to other components (3). It is necessary to identify other components of handwriting as a means of targeting effective intervention strategies (3). Also, it is reported that grade two to four are the best time to screen and evaluate the handwriting performance of primary school students (9).

The first aim of this study was to compare dexterity and two-point discrimination of the hand between primary school-aged children with developmental dysgraphia and healthy children in grade two to four. The second aim was to investigate the relation between dexterity and discriminative touch of the hand in children with dysgraphia.

Methods

Participants

In this descriptive analytic study, 43 students with dysgraphia (27 boys and 16 girls, mean±SD age: 9.28±0.06 years, including 27 right-handed and 16 left-handed) and 55 children with proficient handwriting (32 boys and 23 girls, mean±SD age: 9.57±0.08 years, including 37 right-handed and 18 left-handed) in grade 2 to 4were recruited from special and regular schools. The number of subjects was determined by a sample size estimation using the data from previous studies in which Purdue Pegboard test-retest was estimated (14). The estimation was based on the alpha level of 0.05, a power of 0.90, and it was shown that at least 32 subjects were necessary. Sixty-three percent of children with dysgraphia and sixty-eight percent of normal children were right handed. For each child, the dominant hand was determined by asking them which hand they use for handwriting and drawing. Handedness was verified by observing which hand used to reach out and grasp the pencil (Movement assessment battery for children) (15). Two groups were matched on age, gender, and handedness. Poor handwriting was identified by Persian Handwriting Checklist. Reliability and validity of the checklist are reported (0.6 to 0.93) (16). A psychiatrist diagnosed learning disabled students with dysgraphia by interview, clinical observation and standardized tests. Also, the diagnosis was confirmed by reports of the learning disability center of Tabriz city. Children with documented neurological and behavioral disorders, physical disabilities, hearing and visual problems were excluded from the study. Informed consent was assigned by parents. This study was approved by the ethics committee of Tabriz University of Medical Sciences (Ethical Code: 90-11-13).

Instruments

Purdue Pegboard Test: The Purdue Pegboard model 32020 (Lafayette Instrument-USA) was used to assess hand dexterity including accuracy and speed. Purdue Pegboard is made up of Acrylic board. Its length is 23" & breadth is 11.5". There are 2 center rows each having 25 small holes drilled in them (1/8 in diameter). It has 4 reservoirs across the top for pins, collars, & washers (17).

Two-Point Discrimination Test: For assessing static and dynamic two-point discrimination, we used Touch-Test Two-Point Discriminator (Patterson Medical-UK). Rounded tips are spaced at standard testing intervals from 1-15 mm apart. One disk setting tests from 1 to 8 mm and the other from 9 to 15 mm. Change in settings has been possible just by rotating the top disk until it clicks into place (18,19).

Test-retest, inter and intra-rater reliability of these tests for learning disabled children with dysgraphia was investigated in our previous study. ICCs were ranged from 0.87 to 0.97 for Purdue Pegboard, 0.82 to 0.94 for static two-point discrimination, and 0.69 to 0.91 for dynamic two-point discrimination (18).

Procedures

The assessment process was performed at the learning disability center and primary school in Tabriz city, Iran. An occupational therapist was responsible for all assessments. Children were familiarized with test procedures in a quiet and well-lighted room in a separate session before 48 hours the main assessment session to minimize the possible learning effect.

On the main testing session, children sat behind a table with proper height (approximately 30-inch height) and test instruments were placed in front of them in a random order. The Purdue Pegboard test has four subtests including right hand (subtest 1), left hand (subtest 2), both hands performing simultaneously (subtest 3), and the sum of the first three subtests (subtest 4).The number of pins placed in the holes within 30 seconds was documented as the children's score. Each subtest was administered three times in a row. The average of these three trials was used for data analysis (17).

For two-point discrimination, participants were examined in a standard position: sitting with the forearm in supination, resting comfortably in an armchair or desk and with eyes closed (20).For dynamic examination, the tips of the disc-criminator were placed on the palmar surface of the distal phalanx of dominant thumb, index, and middle fingers and moved from the proximal to distal end of the distal phalanx, over a distance of 1 cm gently (without application of any pressure, only the weight of the instrument) in a random fashion. The initial distance between the two tips was set at 8 mm, and it was gradually decreased until the child could not differentiate between two contact points on his/ her skin. Static two-point discrimination was performed by applying the tips of the disc-criminator to the palmar surface of the distal phalanx of these fingers. Contact with the skin was maintained for 1 second. The initial distance was set at 5 mm gradually decreasing until the participant could not differentiate between the two points. Three trials were done for both static and dynamic two-point discrimination tests. In cases of doubt, the trials were expanded to a maximum of five (19,20).

Statistical analysis

The static and dynamic two-point discrimination scores were not normally distributed based on the Kolmogorov–Smirnov test. Therefore Mann-Whitney test was used to compare differences in static and dynamic two-point discrimination between groups. Correlation among static and dynamic two-point discrimination and Purdue Pegboard scores was examined via Spearman correlation coefficient. Four-way ANOVA was applied to compute the interaction between gender, handedness, and group (normal, dysgraphia) as between subject factors with Purdue Pegboard scores as within subject factor. Pairwise comparisons were performed using Bonferroni adjustment when ANOVA was significant. The significance level was set at $P < 0.05$ for all statistical procedures using SPSS version 18.

Results

There was a significant interaction between group variable (healthy and dysgraphia) and Purdue Pegboard scores ($p=0.002$, Partial Eta squared=0.791). Significant differences were found in Purdue Pegboard scores among children with dysgraphia and normal children except in subtest 2 (Doing the test with the left hand, $p=0.863$) (Fig. 1).

There a significant interaction between group and handedness ($p<0.001$, Partial Eta squared=0.392). Post-hoc comparisons using the Bonferroni adjustment indi-

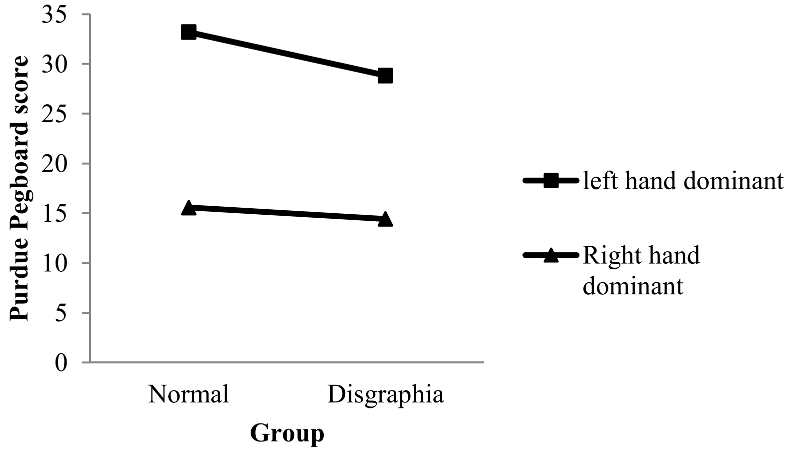

Fig. 1. Interaction of handedness and group for Purdue Pegboard scores. Line ■ demonstrates a significant difference between left-handed dysgraphia children compared to left-handed normal children (p<0.05).

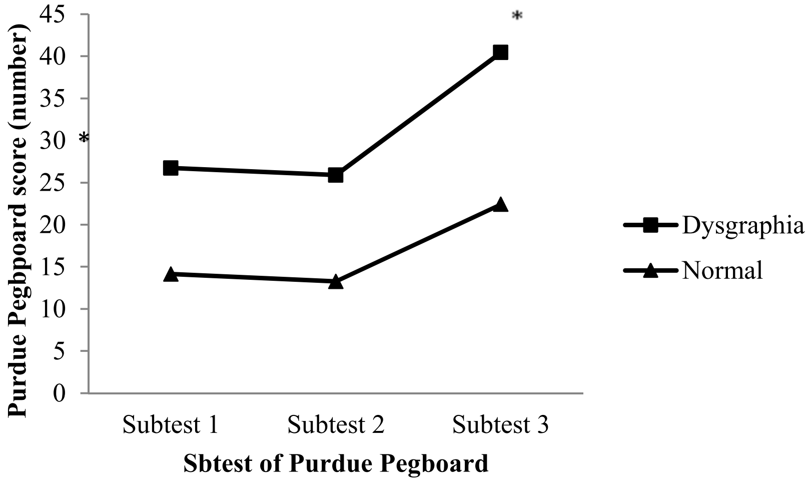

Fig. 2. Interaction of group and Purdue Pegboard subtests for Purdue Pegboard scores. Line ■ demonstrates dysgraphia children and line ▲ demonstrates normal children Purdue Pegboard scores. Subtest 1 demonstrates doing the test with the right hand. Subtest 2 demonstrates doing the test with left hand. Subtest 3 demonstrates doing the test with both hands. * denotes a significant difference between groups (p<0.05).

cated that Purdue Pegboard scores in left-handed children with dysgraphia were significantly lower compared to left-handed healthy children (p<0.001) (Fig. 2).

A Mann-Whitney U test revealed no significant difference in dynamic two point discriminations between two groups of children (p>0.05). Static two-point discrimination was higher in dysgraphia children compared to normal children in all fingers that reached a significant difference in thumb finger (17.63±1.37 vs14.47±1.18; p=0.003).

Unlike normal children, there was no correlation between two-point discrimination and Purdue Pegboard scores of children with dysgraphia (p>0.05).

Discussion

The purpose of this study was to evaluate and compare dexterity and two-point discrimination of the hand between primary school-aged children with developmental dysgraphia and healthy children in grade two to four. The results revealed that dexterity was significantly lower in children with dysgraphia compared to normal children. Handwriting is a complex skill that is accomplished after the child has achieved and integrated underlying perceptual-motor performance components (3). Lack of fine motor control has been reported in poor hand writers (3).Dexterity as a fine motor skill of the hand consists of different components, including in-hand manipulation (3, 21), motor planning and bilateral integration (3). Problems of dysgraphic writers may be related to a lack of fine motor control in the execution of motor programs (3). Cornhill and Case Smith observed positive correlations (high to moderate) between in-hand manipulation and handwriting scores in dysgraphic writers (21). Also, students with bilateral integration difficulties may be unable to dissociate symmetrical and asymmetrical movements of the upper extremity required in handwriting (3). Our study students with dysgraphia obtained lower scores in subtest three of Purdue Pegboard test (performing the test with both hands) compared to healthy children that is in agreement with findings mentioned above (3). Besides, children with poor dexterity pay more attention to motor components of handwriting rather than spelling, letter formation, and sentences structuring which have an influence on automaticity. Lack of automaticity interferes with the handwriting performances (9). Crouch and Jakubecy reported the effectiveness of fine motor activities for correcting handwriting in a second-grade boy with dysgraphia (9). In contrast to our results, three studies reported that dexterity is not a predictor of speed and legibility components of handwriting in children with dysgraphia (22-24). In two studies, slow-writers (grade 2 to grade 6) and poor writers from primary schools participated (22) and in the other study, children with learning and / or behavioral problems were recruited (23) while in this study children were selected from learning disability center without behavioral problems. Also in their study fine motor control was measured by Upper-Limb Speed and Dexterity Subtest of the Bruininks-Oserestsky Test of Motor Proficiency (22-24). The Upper-Limb Speed and Dexterity subtest consists of eight items that involve placing pennies, sorting cards, stringing beads, displacing pegs, drawing vertical lines, and making dots (23). While Purdue Pegboard is an instrument which assesses hand dexterity by placing pins in the holes (17). Therefore, the controversy may be related to differences between instrument selection and inclusion criteria.

Scores of Purdue Pegboard test in left-handers were higher than right-handers in both groups. Our results of healthy children are in agreement with the Judje and Striling who reported that healthy left-handers had higher scores on Purdue Pegboard than healthy right-handers (25). In addition, the results showed that dexterity in right-handers did not differ significantly between healthy and dysgraphic children. According to the result of a meta-analysis, right handed children have better performance in spatial abilities (as a component of hand dexterity) (26). Low scores of Purdue Pegboard were seen in left-handed children with dysgraphia compared to left handed healthy children. To date, this is the first study assessing the effect of hand dominancy in dexterity of children with dysgraphia. It is reported that children with a problem in brain lateralization are susceptible to dysgraphia and dyslexia (27). The average lateralization index is lower in a sample of left-handers. Also, left-handers have a smaller corpus callosum. One hemisphere (presumably the left) would be best suited to language functions and therefore lead to better handwriting performance (26). Therefore the low dexterity of left-handed children with dysgraphia in this study may be partly explained by brain laterality. Further studies are warranted about the relationship between brain laterality and developmental dysgraphia.

Two-point discrimination (static/ dynamic) did not differ between groups. There is controversy on the role of the sensory components of handwriting in learning disabled children (22,28). The results revealed that children with dysgraphia obtained better values for static two-point discrimination which was reached significance in the thumb finger. This finding may be related to more reliance on the sensory information in learning disabled children because of impaired perception (29) and lack of automaticity in motor performance (3,9). More reliance on feedback mechanisms may be due to motor learning problems and less ability to switch to feed forward open-loop mechanisms (10).

There were no correlations between two-point discrimination and Purdue Pegboard scores of children with dysgraphia. According to the literature, other mechanisms such as attention, eye-hand coordination and perceptual problems may be contributing in poor dexterity in children with dysgraphia (3,21,30,31). We did not assess these components in our study. Different types of dysgraphia were introduced in the literature. Sensorimotor function of the hand has an important role in a motor subtype of dysgraphia (3,33,34) but we did not survey the type of dysgraphia in the present study.

Conclusion

Children with dysgraphia had poor hand dexterity compared to healthy children. Two-point discrimination was normal in children with dysgraphia. There were no correlations between two-point discrimination and Purdue Pegboard scores of children with dysgraphia. Based on the results of the present study, we suggest that evaluation process and intervention program in children with dysgraphia should have more focus on components of hand dexterity besides sensory and perceptual strategies. Dominancy also is a factor which can affect hand performance in children with dysgraphia.

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