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The effects of pencil grip posture and different desk designs on handwriting performance in children with hemiplegic cerebral palsy

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Abstract

Objective: The aim of this study was to investigate the effect of different ergonomic desk designs and pencil grip patterns on handwriting performance in children with hemiplegic cerebral palsy and healthy children.

Methods: Twenty-six children with left hemiplegic cerebral palsy and 32 typically developing children were included. The Minnesota Handwriting Assessment was used to evaluate handwriting abilities. Pencil grip posture was assessed with a 5-point rating system. Specifically designed adjustable desks and chairs were used. Four different desk types were used in this study: 1) regular desk; 2) regular desk with a 20º inclination; 3) cutout desk; and 4) cutout desk with a 20º inclination.

Results: Statistically significant differences were found between both groups in terms of handwriting ability ($p < 0.001$). There was no significant difference regarding grip scores between children with cerebral palsy and healthy children ($p > 0.05$). We found that children with cerebral palsy had better performance using cutout desks in relation to rate and spacing parameters of handwriting ($p < 0.05$).

Conclusion: The results of our study demonstrated that the pencil grip patterns have no effect on the handwriting parameters in both children with cerebral palsy and healthy children. It is recommended that a cutout table be used to provide more upper extremity support in handwriting activities for students with cerebral palsy.

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Introduction

Handwriting is an important skill for school-aged children.[1-3] Handwriting difficulties can have implications for a child's successful participation in school and play activities, potentially leading to problems in academic performance and lowered self-esteem.[4-6] A number of correlative studies have identified the performance components that are associated with handwriting, namely, motor planning, eye-hand coordination, visual perception, visual motor integration, kinesthetic perception and in-hand manipulation.[7-12]

Ergonomic factors, as well as the performance components mentioned above, should be considered with the purpose of effectively promoting efficient handwriting skills. Pencil grip, paper position, sitting posture for writing, upper extremity stability and mobility are ergonomic factors that must be analyzed as the child engages in writing.[3,11-15] Several studies have reported the relationship between pencil grip posture and handwriting skills. There are conflicting results about the relationship between pencil grip

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posture and handwriting performance.[11,16,17] However, the application of other ergonomic factors, such as the effect of desk designs on handwriting performance, has been rarely investigated.[18-22] Also, there is limited information about handwriting abilities and ergonomic factors in children with hemiplegic cerebral palsy (CP).

The aim of this study was to investigate the effect of ergonomic desk design and pencil grip posture on handwriting performance in children with hemiplegic CP and healthy children.

Methods

Ethical approval for the study was given by the Hacettepe University Ethical Committee. All families received a written information leaflet, and parents provided written informed consent.

Participants

Twenty-six children who were consecutively referred to pediatric neurology department and diagnosed with left hemiplegic CP by the pediatric neurologist were included in the study. Their ages ranged from 8 to 12. And according to the Manual Ability Classification System (MACS), they were classified in levels 1, 2, and 3 in terms of left hand ability and were right hand dominant. These hemiplegic children were attending a state primary school and were subject to the same curriculum as the healthy children. The control group comprised 32 typically-developing primary school children aged between 8-12 years, with dominant right hand. All children in the control group had a history of normal development without evidence of neurodevelopmental disorders or significant medical problems. They were randomly selected using their identification numbers on the attendance list.

Children in the CP and control group were excluded if they had any orthopedic anomalies, significant visual, auditory and cognitive deficits that would interfere with handwriting performance as documented in the medical record.

When comparing healthy children with hemiplegic children for the purpose of obtaining a homogeneous group as regards hand dominance, all the cases in the healthy group were selected among those with dominant right hands, and all the cases in the CP group were selected among those with left hemiplegia and dominant right hands.

Evaluations were performed in two sessions of 35 minutes each in a silent and quiet room with the purpose of preventing factors such as fatigue and reduction in attention and concentration, which could have an impact on results. There was a 15-minute break between the two sessions. All the tests we used in the study were individually administered to the children by a physical therapist. Children's performance was videotaped for later scoring.

Tasks and procedures

Classification of hand ability

The MACS was used to determine the functional status of the upper extremities in children with CP and to exclude children presenting with excessive impact on the hemiplegic side. Hemiplegic children in levels 1, 2, and 3 according to the MACS were included in the study. The MACS is a new system developed to determine the motor abilities and functionality of the upper extremities and hands in children between 4 and 18 years of age with CP.[23]

Assessment of handwriting

As there are no tests for evaluating handwriting ability developed in Turkey, the Minnesota Handwriting Assessment (MHA) was selected because of its capability to measure the quality of handwriting (rate, legibility, spacing, alignment, size, and form) in children.[24,25] In an initial step, a Turkish version of the test was developed, and word sequences were created that matched the originals. Approvals from class teachers and the Association for the Turkish Language were obtained for the word sequences created. A handwriting test adapted to the Turkish language was tested for validity and reliability by administering it to 60 healthy children in their second and third year of primary school. The intraclass correlation for all the parameters of the writing test was found to be $R1 > 0.95$. Structural validity was shown on 60 healthy children with good and poor handwriting. Children were asked to copy the word sequences in the form given on a line immediately underneath. In the scoring stage, a measure of 0.15 cm was set as the standard length, and all the deviations, and relative proportions of the letters to each other and also the proportions within the letters were assessed by measurement using this standard length.

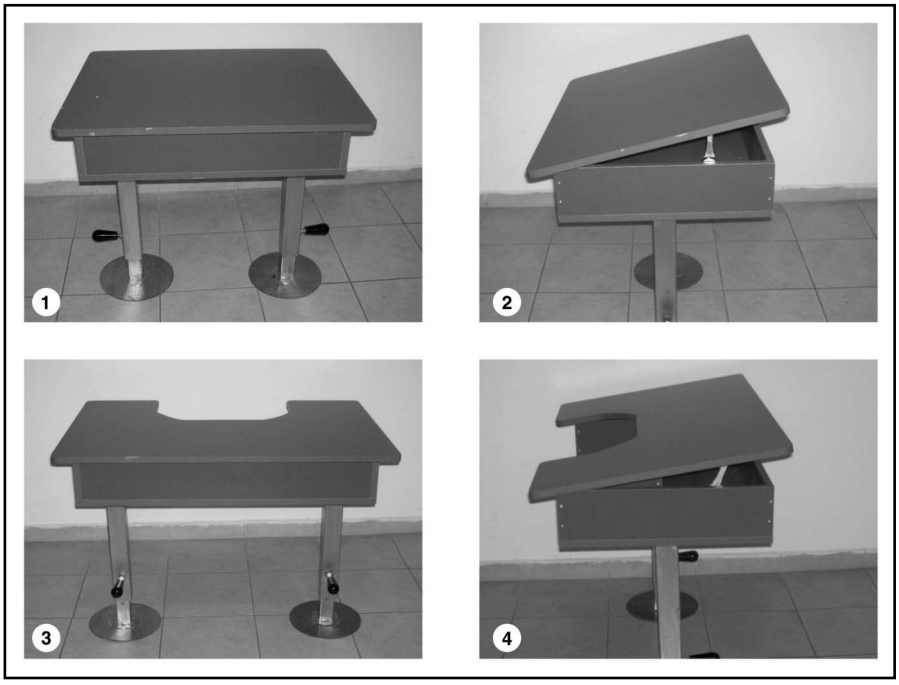
Design of different types of desks

Specifically designed adjustable desks were used. Four types of desks were used in the present study: 1) regular desk; 2) regular desk with a 20º inclination; 3) cutout desk; and 4) cutout desk with a 20º inclination (Figure 1).

The heights of the desks were adjusted according to each subject's elbow height and popliteal height consequently. The children with CP and the healthy children were tested in the four desks. The test order was randomized. Handwriting performance while using the four desks was compared by administering the MHA.

Assessment of pencil grip posture

The components of grip were observed through the use of handwriting assessment. Each child was given a sharpened



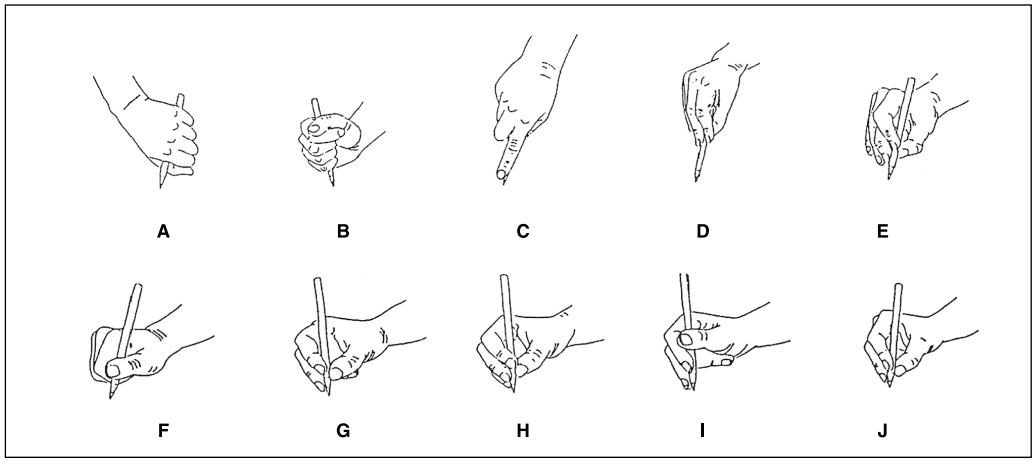
1 = regular desk; 2 = regular desk with a 20° inclination; 3 = cutout desk; 4 = cutout with a 20° inclination.

Figure 1 - Design of different types of desks

pencil and instructed to write words on the handwriting test booklet. Pencil grip posture was assessed with a 5-point rating system with 5 being the highest score possible. Definitions of the grip posture are as follows[16,17]:

- Radial cross palmar grasp: pencil positioned across palm projecting radially, held with fisted hand, forearm fully pronated, full arm movement.
- Palmar supinate grasp: pencil positioned across palm projecting ulnarly, held with fisted hand, wrist slightly flexed and supinated away from mid-position, full arm movement.
- Digital pronate grasp, only index finger extended: pencil held in palmar grasp with index finger extended along pencil toward tip, arm not leaning on the table, full arm movement.
- Brush grasp: pencil held with fingers, eraser end of pencil positioned against palm, hand pronated with wrist movement present, whole arm movement, forearm positioned in the air.
- Grasp with extended fingers: pencil held with fingers, wrist straight and pronated with slight ulnar deviation, forearms moving as a unit.
- Cross thumb grasp: fingers fisted loosely into the palm, pencil held against index finger with thumb crossed over pencil toward index finger, finger and wrist movement, forearm positioned on the table.
- Static tripod grasp: pencil stabilized against radial side of third digit by thumb pulp with index pulp on top of shaft, thumb stabilized in full opposition, wrist slightly extended and hand moving as a unit, pencil resting in open web space, forearm resting on the table.
- Four fingers grasp: pencil held with four fingers in opposition, wrist and finger movement, forearm positioned on the table.
- Lateral tripod grasp: pencil stabilized against radial side of third digit with index pulp on top of shaft of pencil, thumb adducted and braced over or under anywhere along lateral border of index finger, wrist slightly extended, fourth and fifth digits flexed to stabilize metacarpophalangeal arch and third digit, localized movements of digits of tripod and wrist movements on tall and horizontal strokes, forearm resting on the table.
- Dynamic tripod grasp: pencil stabilized against radial side of third digit by thumb pulp with index pulp on top of shaft of pencil, slightly extended, fourth and fifth digits flexed to stabilize metacarpophalangeal arch and third digit, localized movement of digits of tripod and wrist movements on tall and horizontal strokes, forearm resting on the table.

Pencil grip postures are shown in Figure 2. During the handwriting test each child's grip posture was videotaped for later scoring.



A = radial cross palmar grasp; B = palmar supinate grasp; C = digital pronate grasp, only index finger extended; D = brush grasp, E = grasp with extended fingers; F = cross thumb grasp; G = static tripod grasp; H = four fingers grasp; I = lateral tripod grasp; J = dynamic tripod grasp.

Figure 2 - Pencil grip postures[16]

Data analysis

Statistical analyses were performed using the SPSS® software (version 13.0). The means and standard deviations were calculated. To test associations, the Pearson's correlation coefficient was used. The Mann-Whitney U test was applied to test differences in impairments between groups. The effectiveness of the desks was tested for using chi-square test.

Results

The mean age of hemiplegic children was 115.02±5.9 months, and the mean age of healthy children was 107.42±4.36 months. Of the 26 children with hemiplegic CP, 11 (42.3%) were girls and 15 (57.7%) were boys; 16 of the healthy children were girls (50%) and 16 were boys (50%).

According to the MACS, five (19.2%) of the children with hemiplegic CP were level 1, five (19.2%) were level 2, and 16 (61.5%) were level 3.

The handwriting performance was compared between CP and healthy children while using the regular desk. There was a significant difference in all handwriting parameters except for rate ($p < 0.001$). Children with CP had lower scores in all handwriting parameters (Table 1).

The results of this study demonstrated that children with CP had lower grip scores, but there was no significant difference between two groups ($p > 0.05$).

Our data showed that a large percentage of children had static tripod pencil grip. Of the 26 children with hemiplegic CP, 14 (53.80%) used static grip, six (23.07%) used four fingers grip, four (15.38%) used cross thumb grip, one (3.80%) used dynamic tripod grip and one (3.80%) used lateral tripod grip. Of the 32 healthy children, 12 (37.50%) used static tripod grip, 10 (31.25%) used four fingers grip, four (12.50%) used cross thumb grip, five (15.62%) used dynamic tripod grip and one (3.12%) used lateral tripod grip.

When the effects of different desk types on handwriting parameters was compared, we found that children with CP demonstrated better performance at desk 3 in rate and spacing parameters of handwriting ($p < 0.001$, $p < 0.05$). Healthy children demonstrated better performance at desk 2 only in rate parameter of handwriting ($p < 0.001$) (Table 2).

When we investigated the median score of handwriting parameters in the four types of desk, we found that the children with CP got better scores at desk 3 in legibility, form, alignment and spacing parameters, at desk 4 in rate and size parameters. The healthy children got almost similar score in all types of desks.

There was no correlation between grip score and handwriting parameters in CP and healthy children ($p > 0.05$).

Discussion

The results of our study showed that children with left hemiplegic CP with dominant right sides had significantly worse handwriting performance measures (legibility, form,

Table 1 - Comparison of handwriting performance in children with CP and healthy children

	CP (n = 26)	Healthy children (n = 32)	Mann-Whitney U	
Minnesota test	**Mean ± SD**	**Mean ± SD**	**z**	**p**
Rate	9.62±5.06	9.69±4.53	-0.26	0.795
Legibility	29.23±5.87	33.69±0.54	-5.65	0.000*
Form	22.27±7.74	30.44±3.04	-5.35	0.000*
Alignment	22.69±8.88	32.63±2.00	-5.69	0.000*
Size	13.96±12.88	30.06±4.71	-5.38	0.000*
Spacing	27.62±7.13	27.62±7.13	-4.50	0.000*

CP = cerebral palsy; SD = standard deviation.
* $p < 0.001$.

Table 2 - Comparison of the mean scores for the four types of desk on handwriting parameters in children

	Rate	Legibility	Form	Alignment	Size	Spacing
Cerebral palsy						
Desk 1	2.13	2.37	2.29	2.46	2.44	2.67
Desk 2	2.96	2.10	2.13	2.19	2.10	1.92
Desk 3	1.83	2.88	2.98	2.73	2.81	2.83
Desk 4	3.08	2.65	2.60	2.62	2.65	2.58
Chi-square	19.71	6.75	7.42	3.00	4.83	8.54
p	0.000*	0.080	0.060	0.392	0.184	0.036**
Healthy children						
Desk 1	2.27	2.42	2.56	2.70	2.61	2.47
Desk 2	3.11	2.53	2.75	2.48	2.66	2.66
Desk 3	1.94	2.58	2.25	2.50	2.13	2.58
Desk 4	2.69	2.47	2.44	2.31	2.61	2.30
Chi-square	16.2	1.04	2.94	2.62	4.35	1.94
p	0.001*	0.793	0.402	0.455	0.226	0.586

alignment, size, and spacing) compared with healthy right dominant peers. In our study, it was demonstrated that the pencil grip posture has no effect on handwriting parameters.

Children who have diagnosis of hemiplegic CP are a group of children with physical disabilities who commonly attend local mainstream schools. They are generally independent in most activities using their unaffected side and are expected to learn how to write alongside their peers.[26] Dubois et al.[26] demonstrated that the majority of children who have hemiplegia experience difficulties with handwriting (parents reported 75% and teachers 69%).

Studies using standardized handwriting tests to assess handwriting ability are rare. Therefore, studies frequently use tests that evaluate visual motor integration instead.[22,27,28] Standardized assessments of handwriting and underlying components that may contribute to handwriting dysfunction can be a useful aspect of a comprehensive evaluation. In our study, we used the MHA, which is a standardized test developed with the purpose of determining handwriting ability in primary school children. Before administering the test, word sequences in the Turkish language were created to adapt the test to Turkish, and meanings and spelling of the words were checked by class teachers and

the Turkish Language Association. The handwriting test adapted to Turkish was tested for validity and reliability on 60 children in the second and third years of primary school, and constructional validity of the translated version was confirmed by testing on 60 children with good and poor handwriting. The results of our study also demonstrated that the MHA is more appropriate to use for diagnostic and assessment purposes and as outcome measures for children with CP. Since there is no other measure that objectively evaluates handwriting, we believe that the results of our study are important for our country.

Pencil grip is an aspect of handwriting that has been addressed by occupational therapists who work with children with handwriting problems.[16] Although the dynamic tripod grip is generally encouraged by educators and therapists, there are numerous variations of grip. These variations have often been seen in children with poor handwriting. However, it is not clear to what extent an atypical grip contributes to poor handwriting.[17,29] Sassoon et al.[13] showed that the handwriting speed was not affected by an unconventional grip. In contrast, Schneck[17] compared pencil grip pattern in first graders and found that poor writers had lower grip scores. This author suggested that children with handwriting difficulty may demonstrate a lower grip score on a drawing task than children without handwriting problems. Our data showed that a large percentage of hemiplegic and healthy children had static tripod pencil grip. There was no significant difference between the hemiplegic and healthy group. Also, there was no relationship between pencil grip score and handwriting parameters. Ziviani & Elkins[29] demonstrated that speed and legibility were not affected even by the most atypical grip patterns. The same authors concluded that grip does not necessarily adversely affect handwriting performance. The results of our study were similar to those of other studies, indicating that children's pencil grip patterns do not affect their handwriting.

We investigated the effects of four different desk designs on handwriting abilities in hemiplegic CP and healthy children. In our study, children with hemiplegic CP obtained higher scores in rate and size parameters of handwriting while sitting at the cutout desk compared with the use of other types of desks. Hemiplegic children obtained higher scores in spacing, form, legibility and alignment parameters of the handwriting test using the cutout desk with a 20º inclination compared with the use of other desks. Healthy children obtained significantly higher scores only in rate parameter while sitting at the regular desk with a 20º inclination. The results of our study demonstrated that the cutout work surface that was accommodated to the anterior trunk provided better trunk posture and better stabilization for forearm in children with CP.

Shen et al.[22] tested 32 athetoid and spastic diplegic students aged 5-20 years in four workstations. They stated that subjects demonstrated significantly higher motor accuracy scores while writing on the cutout desk. They showed that there was no statistical difference between 20-degree inclined desks and regular desks. There was no control group in their study, students with CP of different types were included in the study, and the range of age of their sample was rather large. Considering that this might have had a negative effect on the study results, we included only 26 children with left hemiplegia and dominant right hands attending second and third grades in primary school. In our study, hemiplegic children were compared with 32 similarly matched healthy children. Our results support the findings of Shen et al. as regards the increasing of handwriting performance by the cutout desk in children with CP. However, in our study, we found that children with CP displayed better performances on 20-degree inclined desks in terms of rate and size parameters, and healthy children displayed better performances with regard to the rate parameter; which is in disagreement with the results obtained by Shen et al.

Posture was identified as a significant factor influencing the performance of children with CP.[30] de Wall et al.[19] demonstrated that the use of a desk with a 10º inclination while reading and writing appears to have a positive effect on posture. They stated that the degree of forward bending of the head is reduced and, therefore, the effort of neck muscles is also reduced.

In our study, we used adjustable desks to decrease the effects of posture on handwriting performance. The heights of the desks were adjusted according to each subject's elbow height. In the present study, we found that a 20-degree inclined desk was effective in rate and size parameters of handwriting in children with CP and in rate parameter of handwriting in healthy children. We consider that an inclined desktop is more appropriate for better visual motor organization.

The results of our study showed that left hemiplegic children with CP with dominant right sides were significantly incompetent in handwriting as compared to their right-dominant peers. Also, in our study, we demonstrated that the pencil grip patterns have no effect on the handwriting parameters in both children with CP and healthy children. The results of our study showed that the cutout work surface elicits significantly better performance than the regular desk in children with hemiplegic CP. It is recommended that a cutout desk be used to provide more upper extremity support in handwriting activities for students with CP. Handwriting performance and academic success of children will thus be improved and they will be able to adapt to the same curriculum as their healthy peers in the primary school period.

By better understanding the ergonomic factors that contribute to and influence handwriting, professionals working in pediatrics will be able to design more efficient intervention programs. Early identification of children with

potential handwriting problems is very important. Screening of handwriting problems may facilitate early intervention in typically developing and high-risk children.

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