

## ORIGINAL ARTICLE

# Relation to visual perception and hand functions of speed and legibility of handwriting in healthy adults

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**Purpose:** This study was planned to investigate handwriting speed, legibility and which visual parameters and which hand function test and grip strength test are the best measures for testing adult handwriting speed and legibility

**Methods:** Seventy-six volunteers aged between 20 and 29 participated in the study. Jebsen-Taylor Hand Function Test's writing subtest, Motor Free Visual Perception Test (MVPT-3), JAMAR was used to grip strength, and Jebsen-Taylor Hand Function, Minnesota, and Purdue Pegboard tests were used. Legibility was calculated by the number of readable written letters.

**Results:** The handwriting speed and legibility were related to visual perception ( $p<0.05$ ). Also, handwriting speed was found correlation with placing, subtest of Minnesota and Purdue Pegboard Hand Function tests, and all parameters, except page turning subtest, in Jebsen-Taylor Hand Function test ( $p<0.05$ ). However, there was no relationship between handwriting, grip and pinch strengths ( $p>0.05$ ).

**Conclusion:** Physical therapists working with young and older people with neurological and orthopedic conditions need to have an understanding of the range of 'normal' handwriting practices and behaviors of healthy adults when retraining handwriting as part of a comprehensive rehabilitation program.

**Keywords:** Handwriting, Visual perception, Grip strength.

## Sağlıklı yetişkinlerde yazı yazma hızı ve okunabilirliğinin görsel algılama ve el fonksiyonları ile ilişkisi

**Amaç:** Bu çalışma, hangi görsel parametrelerin ve hangi el fonksiyon testlerinin, kavrama ve pinç kuvvetlerinin sağlıklı yetişkinlerde yazı yazma hızı ve okunabilirliği ile daha fazla ilişkili olduğunu araştırmak amacıyla planlandı.

**Yöntem:** Çalışmaya 20-29 yaşları arasında 76 gönüllü yetişkin katıldı. Jebsen-Taylor El Fonksiyon Testi'nin yazı yazma alt testi, Motor Yetenek Olmaksızın Görsel Algılama Testi'nin 3. Versiyonu (MVPT-3), JAMAR kavrama kuvveti ve Jebsen-Taylor El Fonksiyon Testi, Minnesota, ve Purdue Pegboard testleri kullanıldı. Yazının okunabilirliği, okunabilir yazılmış kelime sayısı ile hesaplandı.

**Bulgular:** Yazı yazma hızı ve okunabilirliği ile bazı görsel algılama alt testleri ilişkili bulundu ( $p<0,05$ ). Aynı zamanda yazı yazma hızı ile Minnesota ve Purdue Pegboard El Fonksiyon testlerinin alt testi olan yerleştirme ile Jebsen El Fonksiyon testinin ise sayfa çevirme hariç tüm alt testleri arasında anlamlı korelasyon bulundu ( $p<0,05$ ). Bununla beraber, yazı yazma, kavrama ve pinç kuvvetleri arasında herhangi bir ilişki bulunamadı ( $p>0,05$ ).

**Sonuç:** Ortopedik ve nörolojik problemleri olan genç ve yaşlı bireylerle çalışan fizyoterapistler kapsamlı bir rehabilitasyon programının parçası olarak yazı yazmanın yeniden öğretilmesinde sağlıklı yetişkinlerin yazı yazma uygulamaları ve davranışlarının normal sınırlarının anlaşılmasına ihtiyaç duyarlar.

**Anahtar kelimeler:** Yazı yazma, Görsel algılama, Kavrama kuvveti.

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Writing is one of the most effective ways to record information and events, and it can be used to express emotions, thoughts, and ideas.<sup>1</sup> Writing holds a place of primary importance in our lives. Beginning in primary school, students are expected to express their thoughts in writing<sup>1,2</sup>, and adults use handwriting for creativity, communication, and to aid memory.<sup>3</sup> Several skills are essential for writing; it requires integration of sensory, perceptual, motor, cognitive, and language function.<sup>2,4</sup> For instance, visual input influences the ability to know, recall, and discriminate the shape and the spatial orientation of letters; thus, visual perception parameters such as visual scanning, memory, and form constancy affect handwriting.<sup>5,6</sup>

Legibility and speed are critical components of handwriting.<sup>7,8</sup> Legibility refers to readability, or whether what was written can be read by another person, and writing speed refers to the number of letters written per minute.<sup>9</sup> At the same time, pen grip and handwriting style influence handwriting in adults.<sup>10</sup>

At present, computerized systems are generally used to evaluate handwriting.<sup>10-12</sup> However, in everyday life, most people use a pen to take notes, sign their names, and make a shopping list.<sup>10</sup> Thus, to accurately reflect people's daily experience, the present study assessed handwriting created with pen and paper.

Several studies have examined handwriting in healthy people.<sup>3,13,14</sup> Summer and Catarro assessed factors influencing handwriting speed in university students during exams.<sup>14</sup> They collected data concerning pencil grasp, legibility, writing style, pain, fatigue, and academic ability. Rosenblum and Werner, and Van Drempt et al evaluated handwriting in geriatric adults.<sup>3,13</sup> Rosenblum and friends found that geriatric adults had written lower speed and lower pressure. To our knowledge, no study was searched among handwriting parameters and visual parameters, hand function and strengths in the group between young and older adults. However, it is necessary to know that parameters normal ranges for comparing and interpretation data of same ages person with disabilities.

Therefore, the goal of the present study

was to search which visual parameters and which hand function tests, grip and pinch strengths were more related to handwriting speed and legibility in healthy adults. Our hypotheses based on visual parameters, hand function tests and strengths are relationship with handwriting parameters as speed and legibility.

## METHODS

### Participants

The study participants were 76 volunteers (39 men and 37 women) aged between 20 and 29 years. To eliminate possible confounding factors, participants who had an acute trauma or wrist pain were excluded from the study. Ethical approval was obtained from the University of Hacettepe and study protocol was conducted in strict accordance with the Declaration of Helsinki. Informed consent was obtained from all participants.

### Evaluation procedure

Grip strength, palmar pinch, and lateral strength were evaluated using the American Society of Hand Therapists criteria.<sup>15</sup> The participants were tested in the standing position with their shoulder abducted, elbow flexed but not touching the body, and forearm resting in a neutral position. A standard Jamar hand dynamometer was set at the second (for women) or third (for men) handles position. Pinch-strength measurements were made using the first and second digits with the digits held in a C position; palmar strength measurements were taken between the thumb and index and the thumb and middle fingers in a position similar to holding chalk; and the lateral strength measurement was made between the first and second fingers in a position like holding a key. These were evaluated using a manual pinch meter, which measures finger force. All measurements were made on the dominant and non-dominant hands. Three trials at maximum effort were performed for each measurement, and the average value of the three trials was recorded. A 1-min rest period was scheduled between measurements to prevent fatigue.<sup>16</sup>

The hand grip evaluation method described by Kamakura was used for the assessment of hand grip.<sup>17</sup>

The Motor-Free Visual Perception Test, Third Edition (MVPT-3) was used to evaluate visual perception. This valid and reliable test contains items assessing visual discrimination (1-8), form constancy (9-13), visual short memory-I (14-21), visual closure-I (22-34), visual differentiation (35-45), spatial orientation (46-50), figure-ground (51-55), visual closure-II (56-60), and visual short memory-II (61-65) with 65 shapes.<sup>18</sup>

The hand function and writing assessments were evaluated using the Jebsen-Taylor Hand Function Test.<sup>19</sup> This test includes subtests on writing, card turning (simulated page turning), simulated feeding, stacking checkers, picking up small objects, picking up large empty cans, and picking up weighted cans. Recording the number of seconds taken to complete each task scores the subtests. The grips used for picking up large empty cans and weighted cans are not used in handwriting; thus, subtests six and seven were not included in our study. Legibility was calculated using a simple formula devised by Amundson:

**Word legibility percent in a simple formula:**  $Word\ legibility = \frac{Total\ number\ of\ readable\ words}{total\ number\ of\ written\ words}$

Other hand-function tests used were the Minnesota Manual Dexterity Test and the Purdue Pegboard Test. The Minnesota Manual Dexterity Test is composed of five subtests: placing, turning, displacing, one-hand turning and placing, and two-hand turning and placing.<sup>20</sup> Two folding boards and 60 blocks were used in the assessment. Two hand parameters that were not related to handwriting were excluded from the evaluation.

The Purdue Pegboard Test consists of 50 holes arranged in two parallel columns and pegs, washers, and collars.<sup>21</sup> The subject is given 30 s to fill the holes with pegs, first using the dominant hand (defined as the hand used for writing) then the non-dominant hand and then both hands simultaneously. The final task is assembling pegs, washers, and collars. The test score is the number of filled holes.<sup>22,23</sup> The dominant hand was assessed only because that is the one involved in writing.

#### Statistical analysis

The Statistical Package for the Social Sciences version 13 for Windows (SPSS, Inc.,

Chicago, IL, USA) was used to conduct the statistical tests. The results are expressed as the mean  $\pm$  SD, and  $p$ -values  $<0.01$  were deemed statistically significant. The relationships between writing speed and legibility and visual perception, grip strength, and hand function were explored using Pearson's correlation coefficient. Cohen's  $d$  ( $\eta^2$ ) was used to calculate the effect size (effect size;  $0.01-0.06 =$  small,  $0.06-0.14 =$  medium,  $\geq 0.14 =$  large).

## RESULTS

A total of 76 volunteers (39 men and 37 women) aged  $23.38 \pm 1.94$  years participated in the study. The right hand was dominant in 93.4% of the participants, and 6.6% had left-hand dominance. The handwriting style of all participants was printed text.

Handwriting was significantly related to form constancy and spatial orientation. Legibility was significantly associated with visual short memory I, visual closure I, visual differentiation, spatial orientation, visual closure II, visual closure, discrimination, spatial orientation, and total points for visual perception (Table 1). Hand strengths were found as dominant hand grip was  $37 \pm 17.9$ , non-dominant hand grip was  $35.6 \pm 17.6$ , palmar strength was  $7.85 \pm 2.4$  in the dominant hand-  $7.48 \pm 2.6$  in the non-dominant, lateral strength was  $9 \pm 2.02$  in the dominant hand,  $8.56 \pm 2.32$  in the non-dominant hand, pinch strength was  $6.75 \pm 2.26$  in the dominant hand,  $6.4 \pm 2.4$  pound in the non-dominant hand. No correlation of writing speed and legibility with grip, pinch, or lateral or palmar grip strength was found ( $p > 0.05$ ).

Medium-level relationships (Cohen's  $d = 0.06-0.14$ ) were found between handwriting speed and the Jebsen-Taylor Hand Function test scores for simulated feeding, picking up large empty cans, and picking up small objects; placing pegs in the Purdue Pegboard Hand Function Test; and object-placement scores on the Minnesota Manual Dexterity Test. No relationship was found between legibility and the hand-function test scores (Table 2).

Table 1. The relation of right hand left hand writing and legibility with visual perception.

	Dominant Hand				
	Mean±SD	Handwriting speed		Legibility	
		r (p)	η <sup>2</sup>	r (p)	η <sup>2</sup>
<b>MVPT-3 (Point)</b>					
Form constancy	5.810±1.812	0.379 (0.002)*	1	-0.030 (0.824)	0.30
Visual short memory-I	7.652±0.507	0.071 (0.558)	0.98	0.256 (0.047)*	0.54
Visual closure-I	11.680±1.837	0.116 (0.337)	1	0.351 (0.006)*	0.75
Visual differentiation	9.513±1.538	-0.001 (0.996)	0.99	0.319 (0.012)*	0.72
Spatial orientation	3.805±1.274	0.321 (0.007)*	0.99	0.408 (0.001)*	0.69
Figure-ground	3.253±0.926	0.019 (0.883)	0.99	0.285 (0.033)*	0.60
Visual closure-II	3.777±1.077	0.046 (0.708)	0.99	0.499 (<0.001)	0.67
Visual short memory-II	4.291±0.700	-0.002 (0.989)	0.99	0.074 (0.572)	0.51
<b>Total</b>	<b>57.268±4.762</b>	<b>0.187 (0.135)</b>	<b>1</b>	<b>0.549 (&lt;0.001)</b>	<b>0.74</b>

\* p<0.05. r: Pearson's correlation coefficient. MVPT-3: Motor-Free Visual Perception Test. η<sup>2</sup>: Cohen's d.

Table 2. Right and left hand writing and their legibilities' relation with three hand function tests.

	Dominant Hand				
	Mean±SD	Handwriting speed		Legibility	
		r (p)	η <sup>2</sup>	r (p)	η <sup>2</sup>
<b>Jebsen- Taylor Hand Function Test</b>					
	7.272±1.566	0.308 (0.012)*	0.97	-0.073 (0.586)	0.62
	2.440±0.794	0.403 (0.001)*	1	0.226 (0.088)	0.44
	5.126±1.184	0.353 (0.004)*	0.98	0.199 (0.134)	0.36
	4.297±1.291	0.132 (0.289)	0.98	0.038 (0.775)	0.53
<b>Purdue Pegboard Hand Function Test</b>					
	11.336±1.599	0.315 (0.011)*	1	-0.238 (0.077)	0.48
	17.368±6.308	0.089 (0.733)	1	0.192 (0.621)	0.83
<b>Minnesota Hand Function Test</b>					
	66.252±7.657	0.583 (0.001)*	1	0.177 (0.218)	0.41

\* p<0.05. r: Pearson's correlation coefficient. η<sup>2</sup>: Cohen's d.

## DISCUSSION

Recognizing a letter, discriminating between letters, and deciding where to place the letter on paper are all aspects of visual discrimination that influence handwriting.<sup>5</sup> People with a visual memory deficit have difficulty remembering punctuation. Furthermore, writing the same word twice and poor cursive writing, such as using large and small letters together, are associated with deficits in visual perception. A person with a visual discrimination problem who cannot create or recognize shapes may have difficulty recognizing letters and words. Moreover, lack

of visual closure may seriously affect recognition of letters, and a deficit in figure-ground perception is likely to affect copying letters owing to difficulty in separating the letters from the background.<sup>5</sup> Inadequate visual spatial perception may result in the inability to distinguish the margins when writing and to space words evenly.<sup>24</sup> Problems with visual spatial perception may also cause difficulty in determining an appropriate letter size, writing in a straight line, and orienting the paper appropriately.<sup>5</sup> Our finding that writing speed and legibility were significantly associated with parameters of visual perception do not agree with those of Ziviani et al, who

reported no relationship between handwriting and visual perception. However, one researcher emphasized that if a child has difficulties with figure-ground or visual closure they may have difficulties copying and producing letters of an appropriate shape or size.<sup>24</sup> Prunty et al searched any correlations exist between measures of visual perception, visual-motor integration and the handwriting product in children with developmental coordination disorders.<sup>25</sup> However, they did not found any correlation and explained that situations as their tests demonstrated low sensitivity. Methodological differences may explain this discrepancy. They used a visual perception test that required a motor response, whereas present study used visual perception test free motor response. Furthermore, our participants were older, healthy adults in contrast to those used in their study. A search of the literature revealed that the only one study of handwriting in adults was conducted by them,<sup>13</sup> and they called for more studies of handwriting legibility and speed in healthy adults.

The present study did not found any relationship between handgrip and handwriting contrast the results of research by Falk et al, which found a relationship between handgrip and handwriting in children. They used quantitative methods to assess handwriting, but only evaluated grip force, whereas we assessed grip strength and also palmar, lateral, and pinch strength because these grips are used in handwriting.<sup>26</sup> Other grips used while writing by hand may need to be described and evaluated. In present study, handwriting speed was evaluated over a short period of time, so pen grip and hand strength may have had less effect than with tests of longer duration.

Physiotherapists working with people with neurological, rheumatologic, psychiatric and orthopedic conditions need to understand the range of 'normal' handwriting practices and behavior when using handwriting as part of a comprehensive rehabilitation program.<sup>27-29</sup> Furthermore, it is important physical therapists to know the most effective test for evaluating handwriting.

#### **Study limitations and strengths**

A limitation of the present study is that pen-grip patterns were not evaluated. This may not be an important factor for healthy adults;

however, pen-grip patterns affect handwriting in adults with hand impairments. Thus, further research on how pen-grip patterns affected pen-grip strength in healthy adults and in those with a disability are warranted.

The present study found a correlation between hand function and handwriting speed, but no relationship between hand function and legibility. The fact that the hand function and handwriting speed tests were timed, whereas the legibility test was untimed, may account for this difference.

#### **Conclusions**

The results of our study suggest that the Jebsen-Taylor Hand Function Test provides a more accurate assessment of handwriting than does the Minnesota and Purdue Pegboard. This is most likely because the tasks in the Jebsen-Taylor Hand Function Test more closely reflect the motor skills necessary for handwriting compared with the other tests. However, the small sample size does not allow generalization of these results.

In summary, the qualitative methods used in the present study were simple, easy to use, low in cost, and informative. However, quantitative methods can provide detailed information about handwriting factors such as stroke duration. Physical therapists interested in assessing handwriting should use qualitative methods, whereas those wishing to obtain more detailed information should use quantitative methods. An understanding of these relationships and the range of 'normal' handwriting practices are useful for the evaluation and treatment of neurological and orthopedic etc. conditions.

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