

# Handwriting Performance, Motor Coordination and Quality of Life Among Adolescents with Dysgraphia

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**Objectives:** To (1) compare handwriting process measures, motor-coordination performance, and quality of life (QOL) between adolescents with dysgraphia and matched controls, as well as the correlations between those domains among individuals with dysgraphia; Further to (2) examine the contribution of handwriting process measures and motor-coordination performance to the prediction of the physical domain of QOL among adolescents with dysgraphia.

**Method:** Participants included 80 adolescents (13–18 yr), 40 with dysgraphia and 40 matched controls. Adolescents copied a paragraph on paper affixed to a digitizer supplying objective handwriting process measures (Computerized Penmanship Evaluation Tool [CompPET]) and completed the Adult Developmental Coordination Disorder Checklist (ADC motor performance) and World Health Organization Quality of Life Questionnaire brief version (WHOQOL-BREF).

**Results:** Significant group differences were found for the handwriting process (CompPET), motor-coordination performance (ADC), and self-perceived QOL (WHOQOL-BREF). Significant correlations were found between handwriting process measures and motor-coordination ability (ADC-C) and physical QOL. 38% of variability in the adolescent's QOL physical domain was predicted by pen stroke height, duration and current feelings about participants' motor-coordination performance as reflected by others.

**Conclusion:** Results show strongly significant differences in handwriting and motor-coordination performance between adolescents with and without dysgraphia, as in aspects of QOL. Variability in physical QOL can be predicted by handwriting capabilities and motor-coordination performance.

## 1. Introduction

Despite the expending use of technology, handwriting is still a common daily school activity (McMaster & Roberts, 2016). The ability to write is a fundamental component of literacy that is crucial for success in school and most workplace environments (McCloskey & Rapp, 2017). According to the National Handwriting Association (2019), the act of handwriting is a symbolic and visual way for individuals to represent language and concepts in a physical and permanent format. The task of handwriting encompasses sharing of learning and ideas, allows self-expression through the written-text art form, and involves language, cognitive, motor, and perceptual skills all in one activity. Handwriting is typically taught only in the early grades (Wolf et al., 2017), and children typically acquire skillful handwriting performance during the first 3 yr of school (Rosenblum, 2018).

This study focuses on adolescents' handwriting. For high-school students, handwriting is an important gateway to academic success because it supports classroom participation (Graham et al., 1998). Miller et al.'s (2018) systematic literature review showed that difficulties in this area can affect grades, overall self-esteem, and behavior in school settings. Along with spelling and handwriting, difficulties in written expression often are considered manifestations of dysgraphia. The *Diagnostic and Statistical Manual of Mental Disorders* (5th ed.; DSM-5; American Psychiatric Association [APA], 2013) coded dysgraphia as a "Specific Learning Disorder with impairment in written expression." According to Döhla et al. (2018), 7% to 15% of school-age children exhibit some form of development writing deficit. Students with dysgraphia may have poor legibility (e.g., Rosenblum et al., 2003), write slowly (e.g., Graham et al., 2018), and/or experience pain and fatigue while writing (Parush et al., 1998). Research has found that dysgraphia not only disrupts the acquisition of writing skills, but also causes significant emotional frustration for students, is negatively associated with academic functioning, and interferes with the abilities to learn, complete schoolwork, record and communicate ideas, demonstrate knowledge (Kushki et al. 2011; Molitor et al., 2016), and persists over time for many students (e.g., Mayes et al., 2018).

Thus, the detrimental effects of dysgraphia are not limited to children. Adolescents and adults with significant writing deficits may face limited career choices or advancement and have difficulties with everyday tasks that draw upon writing skills (Hen-Herbst & Rosenblum, 2019; McCloskey & Rapp, 2017). Furthermore, researchers have linked fine-motor sequential movement and finger dexterity with handwriting performance among both elementary school students (e.g., Klein et al., 2011) and adults (Weintraub et al., 2010). Motor coordination disorder in adulthood may lead to physical and psychosocial difficulties and to reduced quality of life (QOL; e.g., Barnett et al., 2011).

This study aims to (1) compare handwriting process, motor-coordination performance, and QOL between

adolescents with dysgraphia and matched controls; (2) examine the correlations between handwriting process, motor-coordination performance, and QOL among individuals with dysgraphia; and (3) examine the contribution of handwriting process measures and motor-coordination performance to the prediction of the QOL physical domain among adolescents with dysgraphia.

## 2. Methods

### 2.1 Participants

Participants were 80 adolescents aged 13 to 18 yr. Of them, 40 were defined as having dysgraphia based on the self-reported Handwriting Proficiency Screening Questionnaire (HPSQ-C; Rosenblum & Gafni-Lachter, 2015), Handwriting Legibility Scale (HLS; Barnett et al., 2018), and a semi-structured parent interview. The other 40 were age- and gender-matched controls without dysgraphia. There were no significant differences between the groups in gender or age (dysgraphia:  $M = 15.6 \pm 1.33$ ; controls:  $M = 15.6 \pm 1.49$ ). Adolescents with known neurotic, emotional, or autistic disorders, physical disabilities, or neurological diseases were excluded from the study. All subjects were native Hebrew speakers and writers.

### 2.2 Instruments for Participant Selection

#### 2.2.1 Handwriting Proficiency Screening Questionnaire (HPSQ-C; Rosenblum & Gafni-Lachter, 2015)

The HPSQ-C is a 10-item reliable and valid self-report questionnaire developed to identify school-age children with handwriting difficulties. Cutoff scores were determined as up to 14 for handwriting deficiency and up to 8 for typical writing ability. (See Rosenblum, 2008 for a detailed description.)

#### 2.2.2 Handwriting Legibility Scale (HLS; Barnett, Prunty & Rosenblum 2018)

The HLS was designed to examine performance on five components of legibility, including global legibility (overall readability of the text on first reading), effort to read the script, layout on the page, letter formation, and writing alterations (attempts to rectify written work). Each component is summed to a total score for legibility. Total scores range from 5 to 25, with higher scores reflecting poorer legibility.

### 2.3. Handwriting Process

#### Computerized Penmanship Evaluation Tool (CompPET; previously referred to as POET; Rosenblum et al., 2003)

The CompPET was used to assess participants' handwriting process measures. Participants copied a paragraph onto a sheet of paper affixed to a Wacom Intuos II x-y digitizing tablet (404 x 306 x 10 mm) while using a wireless electronic pen with a pressure-sensitive tip (Model GP-110). This part of the CompPET system enables receipt of the exact time of task performance in s, mean pressure applied towards the writing surface in nonscaled units from 0 to 1024, and mean stroke height reflecting the height of letters in mm.

### 2.4 Motor-Coordination Performance as Perceived During Childhood and Adulthood

#### The Adult Developmental Coordination Disorder Checklist (ADC; Kirby et al., 2010)

The ADC provides further evidence to support developmental coordination disorder (DCD) diagnoses among adults based on *DSM-IV* criteria (APA, 2000). The self-report scale includes 40 items encompassing daily activities in three subscales: (A) difficulties the individual experienced as a child (distinguished from problems acquired in adulthood), (B) individual's perception of his/her performance, and (C) current feelings about the individual's performance as reflected by others. Lower scores represent better performance.

### 2.5 Quality of Life (QOL)

#### The World Health Organization (WHO) Quality of Life Questionnaire, brief version (WHOQOL-BREF; WHO, 1996)

The WHOQOL-BREF measures four QOL domains: physical health, psychological health, social relationships, and health related to environmental factors. The summarized raw score in each domain is translated into a percentage. Higher percentages represent better QOL.

## 3. Results

### 3.1 Differences Between Groups (HPSQ-C and HLS)

As expected, significant group differences were found in the mean HPSQ-C final scores (with dysgraphia:  $20.0 \pm 4.4$ ; controls:  $8.13 \pm 3.6$ ),  $t(78) = 13.07$ ,  $p < .0001$  and total HLS score (with dysgraphia:  $13.59 \pm 4.16$ ; controls:  $7.15 \pm 2.19$ ),  $t(78) = 8.64$ ,  $p < .0001$ ).

### 3.2 Differences Between Groups in Handwriting Process (CompPET)

Mean stroke time, width, and height as measured by CompPET indicated significant group difference,  $F(2,77) = 15.8$ ,  $p < .001$ ,  $\eta^2 = .29$  (Table 1).

**Table 1.** Comparison Between Groups for Handwriting Process Measures ( $*p < .05$ ,  $***p < .001$ )

Handwriting measure (CompPet)	Dysgraphia, $n = 40$	Controls, $n = 40$	$F(1,78)$	$\eta^2$
	$M (SD)$	$M (SD)$		
Mean stroke time (s)	0.31 (0.09)	0.23 (.04)	24.91***	.24
Mean stroke width (mm)	1.90 (0.70)	1.70 (.40)	1.03*	.05

Mean stroke height (mm)	3.10 (1.40)	2.50 (.60)	5.71*	.07
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### 3.3 Differences Between Groups in Motor-Coordination Performance (ADC)

Table 2 shows that significant group differences were found for the three ADC subscales and the total ADC score.

**Table 2.** Comparison Between Groups for Motor coordination Performance, ADC (\*\* $p < .00$ )

Motor-coordination performance measure (ADC) subscale	Dysgraphia, $n = 40$ $M (SD)$	Controls, $n = 40$ $M (SD)$	$F(1,78)$	$\eta^2$
A	2.04 (.48)	1.39 (.34)	48.38***	.38
B	1.94 (.40)	1.36 (.34)	47.55***	.38
C	1.94 (.32)	1.56 (.28)	30.98***	.28
Total	1.96 (.32)	1.47 (.24)	$t(78) = 7.84$ ***	

### 3.4 Differences Between Groups in QOL (WHOQOL-BREF)

Table 3 shows that significant group differences were found between two WHOQOL domains and the total score.

**Table 3.** Comparison Between Groups for Quality-of-Life, WHOQOL (\* $p < .05$ , \*\* $p < .01$ )

QOL measure (WHOQOL)	Dysgraphia, $n = 40$ $M (SD)$	Controls, $n = 40$ $M (SD)$	$F(1,78)$	$\eta^2$
Physical	3.98 (.66)	4.14 (.50)	1.58	.02
Psychological	3.69 (.53)	4.00 (.42)	7.89**	.09
Social	4.14 (.72)	4.04 (.70)	0.39	.01
Environmental	3.92 (.58)	4.16 (.33)	5.77*	.07
Total	3.93 (.47)	4.14 (.31)	$t(78) = -2.35$ *	

### 3.5 Correlations Between Handwriting Process, Motor coordination Performance, and QOL

For adolescents with dysgraphia, significant correlations were found between *mean stroke duration* ( $r = -.38$ ,  $p = .015$ ), *mean stroke height* ( $r = -.36$ ,  $p = .023$ ), and physical QOL. Only the ADC Subscale C (current feelings regarding motor-coordination performance) correlated with QOL: with *physical* ( $r = -.53$ ,  $p = .000$ ), *psychological* ( $r = -.45$ ,  $p = .004$ ), *environmental* ( $r = -.36$ ,  $p = .024$ ), and *total* ( $r = -.49$ ,  $p = .001$ ) QOL scores.

### 3.6 Predicting Physical QOL by Handwriting Process Measures and ADC Scores

Prediction of the QOL physical domain for adolescents with dysgraphia yielded a model that included *mean stroke height* as a significant predictor accounting for 13% of the variance,  $F(1,38) = 5.65$ ,  $p = 0.023$ ; *mean stroke duration* as a significant predictor of an additional 12% of the variance,  $F(1,37) = 5.89$ ,  $p = 0.02$ , and ADC-C (current feelings about the individual's performance as reflected by others) as a significant predictor of an further 13% of the variance,  $F(1,36) = 7.57$ ,  $p = 0.009$  (Table 4).

**Table 4.** Prediction of Physical QOL Among Adolescents with Dysgraphia (\* $p < .05$ , \*\* $p < .01$ , \*\*\* $p < .001$ )

Variable	Model 1			Model 2			Model 3		
	B	SE B	$\beta$	B	SE	$\beta$	B	SE	$\beta$
Stroke height (mm)	-1.67	.703	-.36*	-1.490	0.666	-.322*	-0.987	0.641	-0.212
Stroke duration (s)				2.635	1.085	.348*	1.812	1.043	-1.540
ADC-C							-0.801	0.291	-0.396
$R^2$		0.130			0.249			0.380	
$\Delta R^2$		0.107			0.209			0.328	
$F$ change in $R^2$		5.654*			6.140**			7.345***	

## 4. Discussion

This study aimed to elaborate the knowledge about difficulties in handwriting performance and poor motor coordination in adolescents and examine relationships between these measures and adolescents' QOL. The results indicate that adolescents defined as having dysgraphia show significantly inferior handwriting abilities related to performance time and product legibility quality. These results support previous findings on handwriting processes among younger children (e.g., Rosenblum & Livneh-Zirinski, 2008) and university students (e.g., Rosenblum, 2013). Using the ADC, this study found that the motor-coordination restrictions children with dysgraphia experience continue into adolescence and affect daily activities. These functional restrictions, including handwriting difficulties, were further found to correlate with self-perceptions of the physical health QOL domain. Temporal measures of handwriting and poor motor performance explained 38% of the variance in this domain. To date, handwriting intervention studies and research have been limited to early childhood and elementary-aged students (Schneck & Case-Smith, 2015) despite the understanding that intervention and assessment tools designed for younger students do not support improving writing skills in adolescents (DeMers, 2020). Further research is needed to understand the implications of handwriting difficulties have for academic and nonacademic outcomes in adolescents. However, the significant relationships between handwriting performance and QOL found in this study emphasize the importance of creating services and tools for adolescents with dysgraphia to advance their well-being through interventions, programs, and policies.

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