

# HANDWRITING ASSESSMENT FOR CHILDREN WITH AGE RANGE (4- 12 YEARS OLD): A SCOPING REVIEW

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## **Abstract**

This scoping review aims to explore the existing literature on handwriting assessment in children with developmental disabilities compared to typically developing children, using the Handwriting Frame of References (FOR) as a framework. The study follows the PRISMA-Scoping Review guidelines and retrieves evidence published between 2011 and July 2021 from four databases, including EBSCO, ScienceDirect, Scopus, and Web of Science. The selected articles are evaluated using the Crowe Critical Appraisal Tool (CCAT) for quality, and 30 articles are ultimately included in the study, with CCAT scores ranging from 58% to 88%. The study finds that only three out of the fifteen handwriting assessments align with the handwriting FOR. The selected articles are categorized based on the Handwriting FOR's domain for handwriting performance. The findings reveal that further research is needed to explore the impact of environmental factors on handwriting performance in children. Despite the limitations of this study, such as the restricted search criteria and the use of only one FOR, it provides a comprehensive overview of the existing literature on handwriting assessment in children with developmental disabilities compared to typically developing children. This review highlights the need for standardized handwriting assessments that are in line with the handwriting FOR and suggests that the assessment of environmental factors should be considered when evaluating handwriting performance in children.

**Keywords:** Handwriting, Assessment, Children, Developmental Disability

## **Introduction**

Handwriting problems are among the reasons children seek occupational therapy (OT) services (1). Nearly 40% of students seeking OT services were referred by their teachers or parents who believed the child had handwriting problems, particularly in terms of legibility or speed in transcribing written work (2). The prevalence of handwriting problems in typically developing children has been estimated to be between 5% and 25% (3). The academic task of writing relies on the functional skill of handwriting, which enables students to express written information clearly and efficiently while completing written school assignments within deadlines (4). The assessment of handwriting encompasses the analysis of the written form as well as the various spatial, temporal, and kinematic components that emerge during a child's development (5).

The Handwriting Frame of Reference (FOR) has been a primary guide for occupational therapists in evaluating and treating children's handwriting (6). Recent studies have emphasized the importance of comprehensive measurement that includes all four components when using informal and non-standardized assessments (7, 8). Therefore, it is crucial to utilize a contextually responsive and valid tool to properly evaluate the developmental progression of handwriting skills and identify potential learning disorders through handwriting performance (9).

Typically developing children typically acquire handwriting skills from the age of 6 and above. However, they may experience difficulties in these skills from the age of 4 until primary school due to various factors, such as poor

fine motor control, bilateral and visual-motor integration, motor planning, in-hand manipulation, proprioception, visual perception, sustained attention, and sensory awareness of the fingers. Conversely, children with developmental disabilities, especially those with conditions like Autism Spectrum Disorder (ASD), Attention-deficit/hyperactivity disorder (ADHD), Dysgraphia, Cerebral Palsy (CP), and others, are more likely to face these common challenges (9).

From an occupational therapy perspective, the handwriting FOR serves as a reliable reference for assessing and providing effective interventions for handwriting difficulties (6). While the development of handwriting has been primarily focused on school-age children in both populations of developmental disabilities and typically developing children, less emphasis has been placed on the writing skills of young children before they enter formal schooling. However, fostering handwriting readiness in early childhood may be advantageous for two reasons: (i) Early years handwriting may aid children in improving their reading abilities (10, 11); (ii) Developing "handwriting readiness" skills may contribute to future academic success (12).

The handwriting FOR takes a holistic approach, encompassing all essential writing skills, and is endorsed by occupational therapists in clinical practice. While numerous assessments are available to evaluate handwriting performance and its components, current clinical practice utilizes the handwriting FOR for assessing children's handwriting. To the best of our knowledge, this study aims to map the current practices of evaluating handwriting in children with both typical development and developmental disabilities in parallel with the handwriting FOR. Therefore, there is a need for a scoping review to examine and map the available evidence related to handwriting assessment in alignment with the handwriting frame of reference.

## **Materials and Methods**

### **Study design**

The scoping review adhered to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for scoping reviews (PRISMA-ScR) checklist, which involved recognizing the title and structured summary, identifying rationales and objectives, outlining the methodology, documenting the data, conducting the analysis, reporting the findings, and discussing them (13).

### **Identifying the research questions**

Two research questions guided this review:

- (i) What handwriting assessments are available in recent literature for typically developed and developmentally disabled children?
- (ii) Which handwriting assessments available in recent literature align with the continua of the Handwriting

Frame of Reference (FOR) in terms of domains and key components?

### **Identifying relevant studies**

#### **Search strategy**

The following databases were used to search for relevant published articles: Web of Science, EBSCO, ScienceDirect, and Scopus. The main keywords were guided by Medical Subject Headings (MeSH), such as "handwriting" and "developmental disability" or "developmental disorder." The complete search strategies can be found in Appendix 1. This review focused on populations of children with developmental disabilities and typically developing children. The central concept was handwriting evaluation and assessment.

#### **Eligibility criteria for study selection**

The inclusion criteria were as follows:

- (i) Articles or studies published between 2011 and June 2021,
- (ii) Focus on handwriting assessment of developmental disabilities and typically developing children, and
- (iii) Studies involving children aged four to twelve years old.

However, the following articles were excluded:

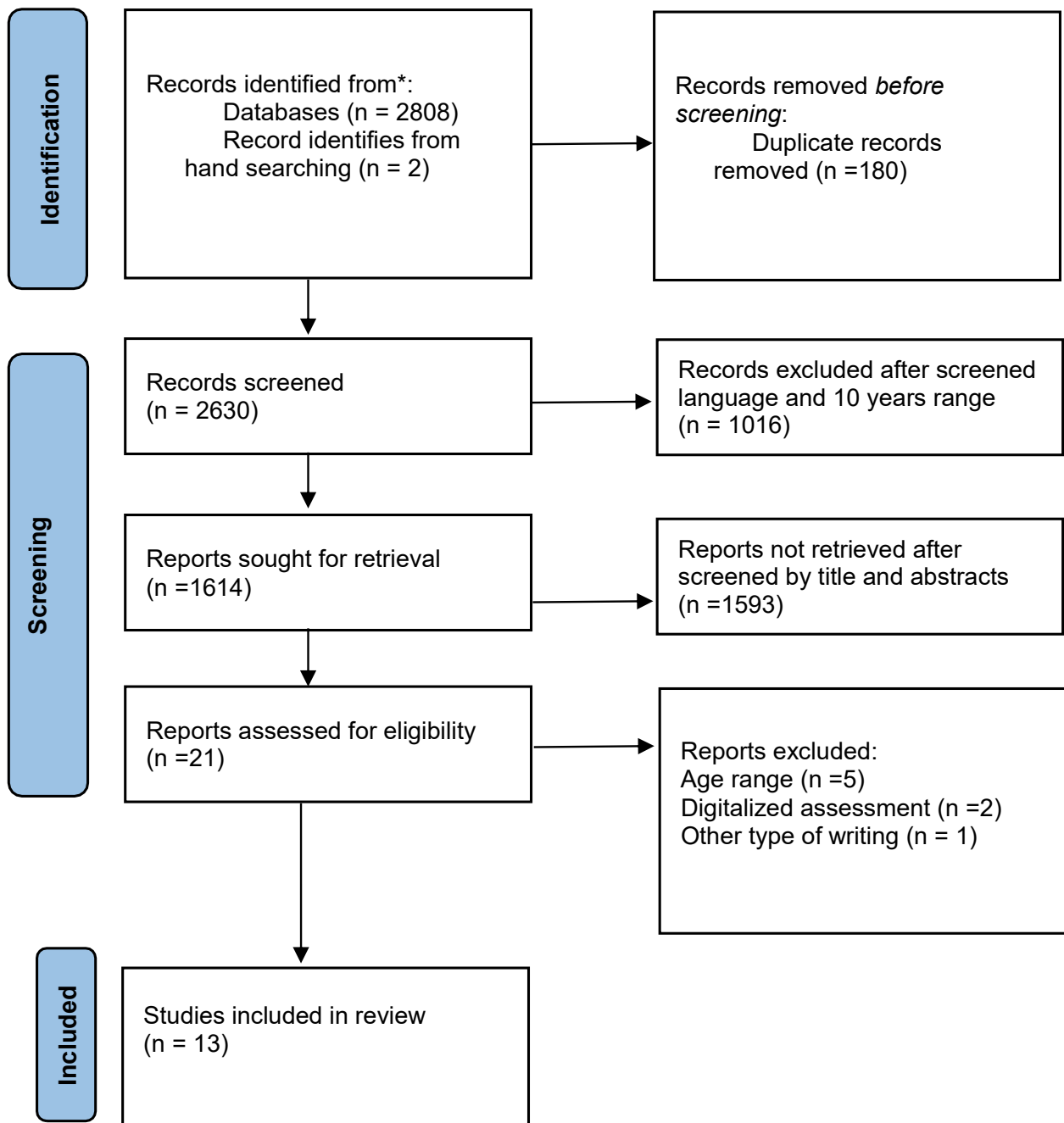
- (i) Studies published in languages other than English,
- (ii) Review papers,
- (iii) Studies published in non-peer-reviewed journals, such as abstracts and paper presentations,
- (iv) Studies using digital-based handwriting assessment.

Six authors were involved in the review process. Firstly, HMH, NAZMZ, NAH, NIAR, MQMS, and AD searched for relevant articles using MeSH terms and variations of text words. Duplicate articles were removed using Mendeley. Then, articles were screened by titles, abstracts, and full texts based on the inclusion and exclusion criteria by NAZMZ and NAH. Finally, all authors independently and manually assessed the eligibility of the articles. Any disagreements were resolved through discussions until a consensus was reached. Data were extracted and reviewed by all authors.

#### **Data extraction**

The study authors, design, subjects, critical evaluation, and findings related to the domains and limitations in the published studies were extracted. Each study was critically evaluated using the Crowe Critical Appraisal Tool (CCAT) (2011) by HMH, NAZMZ, NAH, and NIAR, and the summary was presented in Table 1. The CCAT provides reliability scores and helps readers with varying levels and

Use PRISMA Flow Diagram (13).



**Figure 1:** Flow diagram for the search and study selection in the scoping review.

types of knowledge to draw similar conclusions regarding the research papers.

**Data analysis**

The outcomes were analyzed based on the Handwriting FOR developed by Roston et al. (2). The FOR includes four function-dysfunction continua: writing posture (ocular motor skills, attention, memory), use of writing tools (tool manipulation, dominant hand use, crossing midline using dominant hand), grasp (development of a secure grasp),

and writing legibility (letter formation, size, alignment, spacing). These continua serve as guidelines in occupational therapy evaluations for handwriting difficulties.

**Result**

**i. Study design**

All thirteen studies employed a quantitative research design. More than half of the reviewed studies (n = 9) were prospective cohort studies. One study was conducted as a

**Table 1:** Description of articles in the scoping review

Authors	Study Design	Sample	Instruments	Findings	Critique evaluation / limitation	CCAT Score X/40 (%)
Alhusaini et al. (14)	Quantitative	N = 31 6-8 years old	<b>Handwriting Proficiency Screening Questionnaire (HPSQ):</b> <ul style="list-style-type: none"> <li>Legibility</li> <li>Performance physical</li> <li>Emotional well-being</li> </ul> Minnesota Handwriting Assessment (MHA) (manuscript & D’Nealian styles): <ul style="list-style-type: none"> <li>Ear-point Legibility</li> <li>Speed in copying</li> <li>Form</li> <li>Alignment</li> <li>Size</li> <li>Spacing</li> </ul>	<ul style="list-style-type: none"> <li>The non-proficient handwriters performed significantly poorer on all MHA variables, compared to their peers, except in the rate domain.</li> <li>There was a level of agreement between the teachers’ and therapists’ ratings on handwriting proficiency of the examined first-grade students in all the explored components, except the MHA scale rate category.</li> <li>The standardised and evidence-based tools for evaluating elementary school children’s handwriting performance can help accurately assess handwriting difficulties</li> </ul>	<ul style="list-style-type: none"> <li>Type of sampling method convenience sample instead of random sampling</li> <li>Study findings support measure usage in an international school with English language usage</li> </ul>	31/40 = 78%
Bolton et al. (15)	Quantitative	N = 37  Typical developing children  4-6 years old	<b>Just Write! (JW):</b> <ul style="list-style-type: none"> <li>Total letter accuracy</li> <li>Name writing</li> <li>Pencil grasp</li> </ul>	<ul style="list-style-type: none"> <li>Just Write! (JW): Feasible and able to detect changes</li> </ul>	<ul style="list-style-type: none"> <li>Limited generalizability due to small sample size and unknown intervention receive by sample outward the study settings</li> </ul>	23/40 = 58%
Brossard-Racine et al. (16)	Quantitative	N = 35 Student’s handwriting samples with LD, DC, ASD 7–9 years old	Evaluation Tool of Children’s Handwriting (ETCHM): <ul style="list-style-type: none"> <li>Legibility</li> <li>Alphabet/number</li> <li>Near point</li> <li>Far point</li> <li>Dictation</li> <li>Sentence composition</li> </ul>	<ul style="list-style-type: none"> <li>The therapist’s clinical judgement when assessing handwriting by quantitative findings is acceptable</li> </ul>	<ul style="list-style-type: none"> <li>Poor outcome of the accurate cut-off score and Mild cognitive Intellectual deficiency due to interrater reliability</li> </ul>	31/40 = 78%
Cermak and Bissell (17)	Quantitative	N = 40  Students with and without handwriting difficulties  7-11 years old	Here’s How I Write (HHIW): <ul style="list-style-type: none"> <li>Affect, or how the child feels about his or her handwriting (2 items)</li> <li>Performance, or how the child thinks he or she performs various components of handwriting (19 items)</li> <li>Physical factors, or body posture, stabilisation of the page, and fatigue when writing (3 items)</li> </ul>	Here’s How I Write (HHIW): <ul style="list-style-type: none"> <li>Measure content freed from gender and cultural bias</li> <li>Able to discriminates between good and poor writers</li> <li>A significant association between teacher and student when teachers rated lower score for poor handwriting sample compared to students</li> </ul>	<ul style="list-style-type: none"> <li>Limited generalizability due to sample size, and study limited to one geographical area</li> </ul>	31/40 = 78%

**Table 1:** Description of articles in the scoping review (review) (continued)

Authors	Study Design	Sample	Instruments	Findings	Critique evaluation / limitation	CCAT Score X/40 (%)
Donica, Massengill, and Gooden (18)	Quantitative	N = 46 6-8 Years old	<b>The Print Tool:</b> Memory <ul style="list-style-type: none"> <li>• Orientation</li> <li>• Placement</li> <li>• Size</li> <li>• Start</li> <li>• Sequence</li> <li>• Control</li> <li>• Spacing Skills</li> </ul> <ul style="list-style-type: none"> <li>• <b>THS-R:</b></li> <li>• Memory</li> <li>• Dictation</li> <li>• Near-point Copying</li> </ul>	<ul style="list-style-type: none"> <li>• Unclear relationship of grasping development to legibility</li> </ul>	<ul style="list-style-type: none"> <li>• Limited generalizability with small sample (Specific rural location)</li> </ul>	33/40 =83%
Donica and Francis (19)	Quantitative	N = 50 4-5 years old	<b>Shore Handwriting Screening (SHS):</b> <ul style="list-style-type: none"> <li>• Postural control</li> <li>• Hand control</li> <li>• Pre-Writing skills</li> <li>• Letter and number formation</li> <li>• Bilateral hand skills</li> <li>• Bruininks-Oseretsky Test of Motor Proficiency (BOT)</li> </ul>	Shore Handwriting Screening (SHS): <ul style="list-style-type: none"> <li>• Moderate to high correlation with fine manual control portions of the BOT-2 for the lower socio-economic group.</li> <li>• Low to moderate correlation for the same portion in the higher socio-economic group.</li> </ul>	<ul style="list-style-type: none"> <li>• The scoring between two different social-economic could be affected as scored by different researchers when data collection</li> </ul>	26/40 =65%
Duiser et al. (20)	Qualitative	N = 173 Typical developing children 7-11 years old	<b>Concise Assessment Scale for Children's Handwriting (BHK):</b> <ul style="list-style-type: none"> <li>• Speed</li> <li>• Legibility off hand-writing</li> <li>• Fine Motor Ability</li> </ul>	<b>Concise Assessment Scale for Children's Handwriting (BHK):</b> <ul style="list-style-type: none"> <li>• The sensitivity and positive value were poor</li> <li>• a significant predictor of handwriting quality was initial handwriting before training</li> <li>• no significant developmental model was revealed for speed components</li> <li>• Findings indicate improvement in quality and speed of handwriting increased with years of training (2-3 years period)</li> </ul>	<ul style="list-style-type: none"> <li>• The usage of BHK for screening persistent handwriting issues with extra vigilant</li> </ul>	33/40 =83%
Hartingsveldt et al. (21)	Quantitative	N = 251 Typical developing children 5-6 years old	<b>Writing Readiness Inventory Tool in Context (WRITIC):</b> <ul style="list-style-type: none"> <li>• Copying,</li> <li>• Tracing</li> <li>• Arm &amp; wrist positioning</li> <li>• Pencil grip</li> <li>• Pencil pressure</li> </ul>	Writing Readiness Inventory Tool in Context (WRITIC): <ul style="list-style-type: none"> <li>• Content validity was having 94.4% agreement from the experts.</li> <li>• The performance of paper and pencil tasks components had Cronbach's alpha of 0.82 and 0.69, respectively.</li> <li>• The groups (good performers and poor performers) showed significant differences in two subdomains: "Sustained attention" and "Task performance".</li> <li>• Feasible for use in the classroom.</li> </ul>	<ul style="list-style-type: none"> <li>• Presence of bias due to 10 raters involved Measure being developed almost after the prewriting stage</li> </ul>	32/40 = 80%

**Table 1:** Description of articles in the scoping review (review) (continued)

Authors	Study Design	Sample	Instruments	Findings	Critique evaluation / limitation	CCAT Score X/40 (%)
Havaei et al. (22)	Quantitative	N = 1262 (Persian-language elementary school students)  7-9 years old		<ul style="list-style-type: none"> <li>PHAT had two separate factors in copying and dictation domains including global legibility (formation and space) and inclination (alignment and text slant)</li> <li>Acceptable internal consistency, excellent test-retest, and inter-rater reliability between teachers, good to excellent inter-rater reliability between teachers and the occupational therapist were reported</li> </ul>	<ul style="list-style-type: none"> <li>Environmental factors such as noise and inadequate light can affect handwriting performance</li> </ul>	31/40 = 78%
Matta Abizeid et al. (5)	Quantitative	N = 763 Lebanese children 6-11 years old		<ul style="list-style-type: none"> <li>The BHK was an acceptable measure in identifying dysgraphia and poor handwriting in Lebanese children</li> <li>Gender and absence of handwriting issues student improved in the speed of writing in 5 minutes throughout the observation</li> </ul>	<ul style="list-style-type: none"> <li>Different graphic systems could provoke an interference when being compared between two population</li> <li>Factors such as reducing handwriting quality may explain the contrast of handwriting quality of Lebanese and French children.</li> </ul>	29/40 = 73%
Salameh-Matar et al. (23)	Quantitative	N = 114  Typical developing students  7-10 years old		<p>Arabic Handwriting Assessment (A-HAT):</p> <ul style="list-style-type: none"> <li>Medium to high test-retest and inter-rater reliability</li> <li>Good construct validity and was stable across tasks</li> <li>Improvement speed and legibility for copying and dictation skills</li> <li>Girls' handwriting legibility more than boys for dictation skills</li> <li>The needs to consider different language orthography of a language when developing a measures</li> </ul>	<ul style="list-style-type: none"> <li>Limited generalizability due to sample size, age range and geographical areas</li> <li>More accurate criteria for legibility in copying tasks</li> </ul>	35/40 = 88%

**Table 1:** Description of articles in the scoping review (review) (continued)

Authors	Study Design	Sample	Instruments	Findings	Critique evaluation / limitation	CCAT Score X/40 (%)
Tse, Siu and Li-Tsang (24)	Quantitative	N = 151  Typical developing children 3 – 5 years old	<b>Chinese and English Handwriting Screening Test for Kindergarten Children (CHEST):</b> <ul style="list-style-type: none"> <li>Legibility of Handwriting</li> </ul> Chinese Version: <ul style="list-style-type: none"> <li>Alignment</li> <li>Stroke formations</li> <li>The proportions between strokes and radical out of the grid</li> </ul> <ul style="list-style-type: none"> <li>English version</li> <li>Alignment</li> <li>Spacing</li> <li>Size between letters</li> </ul>	<ul style="list-style-type: none"> <li>The CHEST:Primary screening measures develop in Chinese and English</li> <li>The similar task is to copy a group of familiar words.</li> <li>Establishment objective measure to identify and describe children's problems for copying skills</li> </ul>	<ul style="list-style-type: none"> <li>The teacher's perception determines the student's handwriting issues based on handwriting samples</li> </ul>	33/40 = 83%
Van Waelvelde et al. (25)	Quantitative	N = 860 Flemish children 7-12 years old	<b>Dutch SOS test:</b> <ul style="list-style-type: none"> <li>Handwriting speed</li> <li>Legibility or readability judged globally</li> <li>Specific features that characterize readability</li> </ul>	Dutch SOS test: <ul style="list-style-type: none"> <li>Affirmed convergent validity.</li> <li>Provides discrimination between typically developing children and children, gender, and age groups.</li> </ul>	<ul style="list-style-type: none"> <li>The conciseness of the components of the measure shields a more depth handwriting evaluation</li> </ul>	32/40 = 80%

longitudinal and retrospective cross-sectional study, while the remaining two studies were a cross-sectional study and a normative cohort study, respectively.

### ii. Study location

The previous studies were predominantly conducted globally. They were carried out in the United States (n = 4), China (n = 4), Netherlands (n = 1), Lebanon (n = 1), Iran (n = 1), Belgium (n = 1), Canada (n = 1), and Saudi Arabia (n = 1).

### iii. Population

The participants' age ranged from 3 to 12 years, and they were recruited from various settings such as hospitals, clinics, kindergartens, and schools. The sample sizes ranged from 31 to 1,262 participants and included both typically developed children and children with developmental disabilities.

### Summary of findings based on the handwriting FOR:

#### i. Writing posture

Four studies assessed writing posture for children's handwriting performance (14 - 17). The Grasp Checklist evaluated a student's working posture, writing movements, and specific grip components. The checklist observed handiness, trunk alignment, paper position, and the placement of the non-dominant hand. The authors

reported an unclear relationship between grasping development and legibility (15). The Writing Readiness Inventory Tool in Context (WRITIC) focused on the positioning of the arm and wrist during writing readiness evaluation. The third item of the inventory, the paper-and-pencil task sub-item, examined the child's sitting posture quality. The child's performance was then scored on a three-point scale (2=good, 1=doubtful, 0=insufficient) based on the arm and wrist movement while completing tasks such as coloring, writing names, pre-writing shapes, and copying numbers and letters. The authors used Here's How I Write (HHIW), which was developed as a child's self-assessment to address their perception of their handwriting using a card game interview and to set goals for monitoring progress (18). The assessment focused on physical factors (3 items), including body posture, page stabilization, and fatigue when writing. All 24 items were scored on four scales (1=always, 2=usually) as positive scoring and (3=usually, 4=always) as negative scoring. The Handwriting Proficiency Screening Questionnaire (HPSQ) evaluated physical performance and emotional well-being (5-8 items) from a total of 10 items. All items were assessed using the Likert scale (0=never, 4=always), with higher scores indicating poor performance (19). Lastly, the Shore Handwriting Screening (SHS) assessed postural issues such as students' feet on the floor, sitting on feet, standing at the desk, wrapping feet around the chair, often sitting with the head down, and excessive fidgeting at the desk through observation (20).



## **ii. Use of tool**

Only one study assessed the use of tools, such as tool manipulation, dominant hand use, and crossing the body's midline with the dominant hand (20). The Shore Handwriting Screening (SHS) measured hand dominance and the use of other tools, such as rotating pencils and erasers (20).

## **iii. Grasp**

Four studies evaluated the student's ability to securely grasp the writing instrument and manipulate it easily without experiencing fatigue or pain in the hand or wrist while completing assigned academic tasks (15, 16, 19, 21). The Print Tool, Test of Handwriting Skills-R, and Grasp Checklist revealed that therapists should not change a student's grasp pattern solely because of an atypical grasp pattern if it does not affect handwriting performance (20). The Writing Readiness Inventory Tool in Context (WRITIC) focused on pencil grip and pressure (18). Just Write! (JW) assessed students' pencil grasp through observation using a 6-point Likert scale (0=unable to grasp, 1=immature grasp (1), 2=immature adult grasp, 3=emerging adult grasp, 4=adaptive adult grasp, and 5=adult-like grasp) (22). The Shore Handwriting Screening (SHS) assessed hand grasp based on three levels of immature, transitional, and mature pencil grasp patterns (20).

## **iv. Writing legibility**

All thirteen studies focused on writing legibility using various tasks and goals, such as legibility and speed of writing. Only one study included tracing tasks in handwriting legibility (18). For copying skills, whether near or far point, eight studies examined handwriting legibility (14, 15, 17-20, 23, 24). Additionally, four studies assessed children's handwriting performance in legibility for dictation skills (15, 17, 23, 24). Two studies included tasks of name writing, which require early exposure and practice (15, 21). The letter and number formation skills were assessed in seven studies, focusing on each symbol's forms, unique characteristics, and memory-based tasks (14, 15, 19, 22-25). Seven studies emphasized the speed of handwriting completion (14, 15, 17-19, 22, 25). Other essential aspects of handwriting legibility, such as sizing, spacing, and alignment of uppercase and lowercase letters, were assessed in six studies (5, 14, 15, 19, 20, 24).

## **Other components:**

### **i. Children factor**

Three studies assessed a child's emotions and interest in handwriting (18, 19, 21). The "Child" domain included six questions regarding the frequency, interest, and perceived competence in drawing/coloring and handwriting. In addition, one item in the WRITIC was scored by the tester to evaluate sustained attention during performance. All items were scored on a three-point scale (2=good,

1=doubtful, 0=insufficient) (18). The Here's How I Write (HHIW) included 21 items on how the child felt about their handwriting (2 items) and the child's perception during various components of handwriting (19 items) (21). The HPSQ assessed items 5-8 for physical and emotional well-being, scored on a Likert-type scale from 0 (never) to 4 (always), with higher scores indicating poor performance. Based on a previous study, children who received a final score of  $\geq 14$  from the overall items were considered non-proficient writers, while those with a score below 14 were considered proficient handwritings (19).

### **ii. Environmental factor**

Three studies evaluated environmental factors (18, 24). The second item assessed in the WRITIC was also an environmental factor, evaluating the physical environment (desk and chair height) and the social context (class climate), which was not emphasized as one of the components of the handwriting FOR (18). On the other hand, the Shore Handwriting Screening (SHS) also assessed environmental factors such as the height of the desk and chair, as well as external factors like sound, lighting, and desks located reasonably close to the point of instruction (teacher), through classroom observation during the screening period (20).

Multiple assessment tools were used in the articles, employing different outcomes and measurement methods through standardized and non-standardized tools. The assessments used in the studies are listed in Table 2.

## **Discussion**

This scoping review aims to review and map the available evidence related to handwriting assessment, parallel with handwriting skills. Our study included over half ( $n = 13$ ) of quantitative studies. Quantitative research was widely used in assessing effectiveness studies (26). Quantitative study places emphasis on numbers and figures in the collection and analysis of data (27). Therefore, the approach of this research should be seen as scientific. In addition, it is proposed that the quantitative design is more applicable from the perspective of a handwriting assessment involving scientific methods for data collection and analysis to enable generalization. Replicability is another benefit derived from the use of this research approach.

Our study showed that the study location was homogeneous with the Western country population. Generalization of handwriting development should be made carefully as it is a complex test and often related to cultural issues, as each culture differs in locales and undergoes constant changes (28). However, the findings from a sample could only be referred to the defined population from the selected representative (29). For the sample size, there were only 31 to 1,262 subjects in the thirteen studies overall. Hence, the optimal sample size to ensure adequate power samples to detect statistically significant results was decreased (30).



**Table 2:** Assessment used in the handwriting assessment studies

Authors	Handwriting Assessments															
	HPSQ	MHA	JW	ETCH	HHIW	TSH-R	TPT	GRASP CHECK LIST	SHORE	BHK	WRITIC	PHAT	L-BHK	A-HAT	CHEST	SOS
Alhusaini et al. (14)	√	√														
Bolton, Stevenson and Janes (15)			√													
Brossard-Racine et al. (16)				√												
Cermak and Bissell (17)					√											
Donica, Massengill and Gooden (18)						√	√	√								
Donica and Francis (19)									√							
Duiser et al. (20)										√						
Hartingsveldt et al. (21)											√					
Havaei et al. (22)												√				
Matta Abizeid et al. (5)													√			
Salameh-Matar et al. (23)														√		
Tse, Siu and Li-Tsang (24)															√	
Van Walvede et al. (25)																√

HPSQ: Handwriting Proficiency Screening Questionnaire MHA: Minnesota Handwriting Assessment

JW: Just Write!

ETCH: Evaluation Tool of Children’s Handwriting HHIW: Here’s How I Write

TSH-R: Test of Handwriting Skills-Revised TPT: The Print Tool

BHK/ L-BHK: The Concise Evaluation Scale for Children’s Handwriting/ Lebanese WRITIC: Writing Readiness Inventory Tool in Context

P-HAT: Persian Handwriting Assessment Tool A-HAT: Arabic Handwriting Assessment Tool

CHEST: Chinese and English Handwriting Screening Test for kindergarten children SOS: ‘Systematische Opsporing Schrijfproblemen’ or S

**(i) Writing posture**

A good writing posture is the ability to maintain an upright sitting position without fatigue during handwriting tasks (31). Our study found that a good writing posture was crucial for handwriting performance (32). However, writing posture was also found to be insignificant between excellent and poor writers (18). Nevertheless, posture is preliminary and essential for handwriting (33). A good posture may prevent fatigue, pain, and disorders so that children can participate longer in tasks (34). On the other hand, this may not necessarily be true for children with

Cerebral palsy. A dynamic seating position was proposed to accommodate this condition due to abnormal patterns of movement, which limit their ability to move. The specialized seating position provided benefits of improved functions, more comfort, and improved the writing performance of children with cerebral palsy (35).

**(ii) Use of writing tools**

Prerequisite skills for legible handwriting include in-hand manipulation, hand dominance, and crossing the body midline with the dominant hand. Consistent with prior

research, in-hand manipulation skills were essential to handwriting development because the skills enable writers to adjust, reposition, or move the writing instruments (36). Children should be able to place writing paper in the middle of the body for practical use. Besides that, with the same hand for writing, children should be able to turn the pencil over to erase (37). Our study found a linear relationship between fine motor skills and handwriting performance. Therefore, developing fine motor skills through daily activities since early childhood would facilitate good handwriting performance (30). In addition, establishing hand dominance by the age of 4 to 6 years old was considered a vital motor skill that significantly impacts areas of education such as handwriting (38).

### **(iii) Grasp**

Current literature illustrates significant differences in grasp patterns between poor and good writers (18). Prior research found no statistically significant difference between handwriting performance and different grasp patterns (15, 18, 20). Parallel to these findings, occupational therapists in this field have long believed that students must employ a dynamic tripod grip to write legibly. However, research has shown that this assumption needs to be corrected (39). It is supposed that children's handwriting performance should focus on legibility and speed (37).

### **(iv) Writing legibility**

Legibility in handwriting is based on letter formation, size, alignment, and spacing when participating in educational activities (40). Our study found a significant difference in writing legibility (sizing, alignment, letter formation, spacing, and speed) in copying, spelling, and dictation tasks (15, 17, 18-20, 22, 23, 25). However, studies state that writing legibility alone cannot evaluate handwriting performance without considering other handwriting components such as writing posture, use of tools, and grasp pattern (5, 14, 16, 21, 24). This is because children may apply more force or have more axial force variability, both of which have been shown to reduce legibility in the past (31). Handwriting, especially legibility, is most often affected by position factors such as sitting and lying (39). On the other hand, the grip has little consequence on handwriting legibility and speed (37). It is also known that writing speed is variable depending on the context, the instruction given, and whether the child is copying, taking dictation, or free writing (9). However, it would be challenging to develop a valid, reliable handwriting screening tool that would cover every aspect of handwriting performance (41).

On the other hand, children's emotions and personal components, such as the child's interest and perception of performance in paper-and-pencil tasks, were reported as not significantly affecting handwriting performance (18). However, another study demonstrated a significant difference in children's handwriting performance with

their emotional and personal affect (21). Besides that, observations by clinicians found that children with dysgraphia who erased more complained about exhaustion or hand pain and were unwilling to write and perform their schoolwork, in addition to legibility and timing deficiencies. All of these signs may be considered to represent a category of physical and emotional well-being (2). In addition, other findings showed that children's self-efficacy in handwriting might be impacted by their inability to write as expected (9). Furthermore, our study findings showed that environmental factors such as physical (desk, table, chair, sound, and lighting) and social context (peers) had no linear relationship with handwriting performance (19). At the same time, findings from different studies highlighted the important role of environmental factors in handwriting tasks (20).

### **Implications and limitations**

This review provides significant implications for the findings concerning handwriting measures for developmentally disabled and typically developed children. This is the first study on handwriting measures that were guided based on the handwriting frame of reference. This review may serve as an initial reference for occupational therapists to differentiate and select handwriting assessments that comply with the handwriting FOR, which is believed to encompass all the crucial aspects concerning the domains of handwriting. However, this review does not include all studies, especially articles not written in English and confined to limited databases. Furthermore, other review studies and studies published in non-peer-reviewed journals, such as abstracts and paper presentations, were also omitted from the search. Therefore, the generalization of the results should be made carefully, and future studies are needed to verify the issues that arise from this study.

### **Conclusion**

This scoping review is considered suitable for current Occupational Therapy practice as it outlines contemporary handwriting FOR and classifies the findings according to the components contained in the handwriting FOR. To highlight the significant findings in this review, the Minnesota Handwriting Assessment (MHA), Shore Handwriting Screening (SHS), and Writing Readiness Inventory Tool in Context (WRITIC) have been identified as occupational-based assessments that cover all four FOR components in handwriting. Additionally, it is crucial to consider two additional components, namely the children and the environmental factors, during evaluation to avoid neglecting underlying skills and to enhance the child's performance in handwriting holistically.

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The authors declare no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

### Ethical clearance

Not applicable.

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## Appendix 1

Search strategy for four databases:

Database	Search Strategy
Scopus	((handwriting*) AND (asses* OR tool* OR instrument* OR test* OR battery* OR measure*)) AND ("developmental disability*" OR "developmental disorder*")
EBSCO	((handwriting*) AND (asses* OR tool* OR instrument* OR test* OR battery* OR measure*)) AND ("developmental disability*" OR "developmental disorder*")
Web of science	TS= ((handwriting*) AND (asses* OR tool* OR instrument* OR test* OR battery* OR measure*)) AND ("developmental disability*" OR "developmental disorder*")
Science Direct	((handwriting) AND (asses OR tool OR instrument OR test OR battery OR measure)) AND ("developmental disability" OR "developmental disorder")